CHINA'S WATER SITUATION IN 1999
A TRIP REPORT

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U.S. Department of Agriculture
Agricultural Research Service
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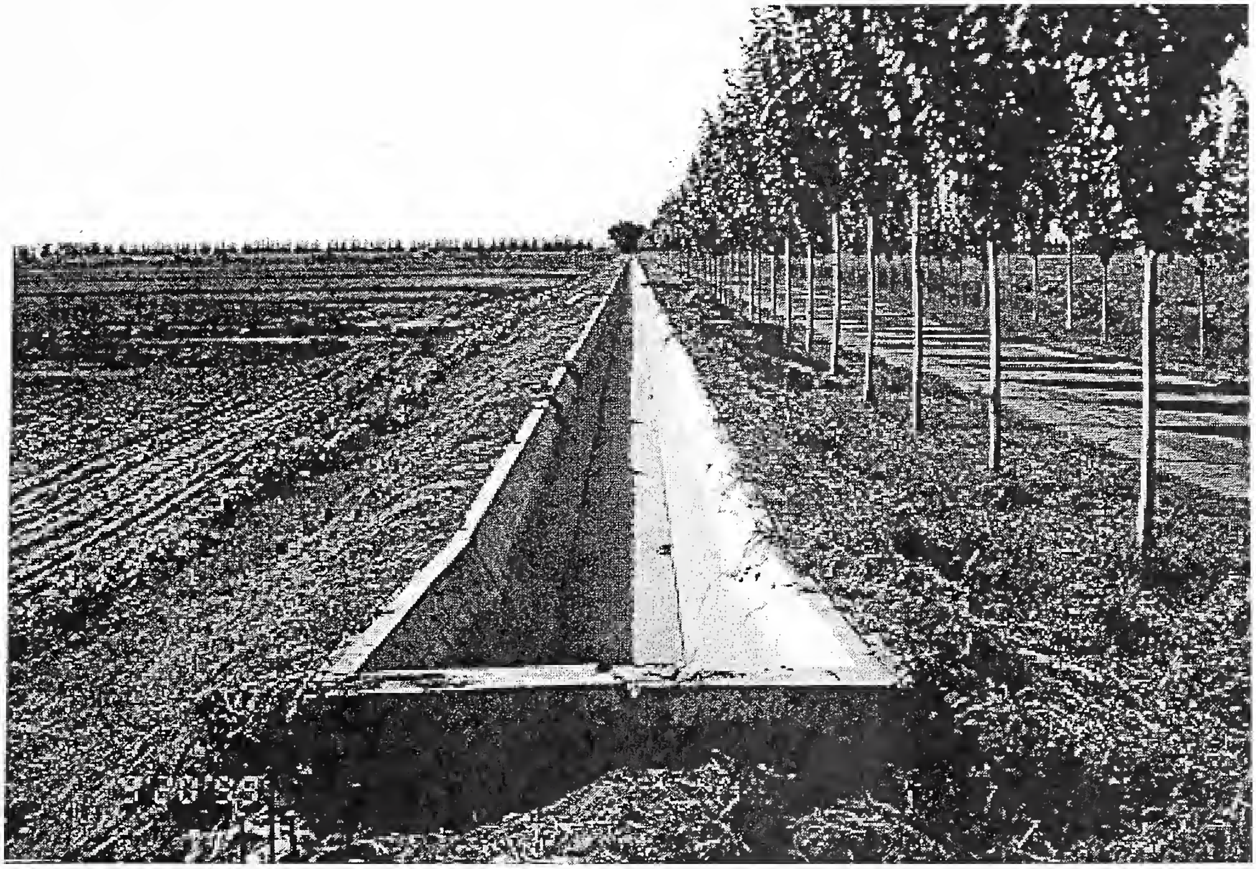

Concrete Lined Irrigation Ditch
Tianjin

U.S. Department of Agriculture
Agricultural Research Service
Economic Research Service
Natural Resource and Conservation Service
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Preface

The U.S. Department of Agriculture Water Team collected a large quantity of information about the current water situation in China. Government and Communist Party officials, scholars, and private citizens openly shared information with the Team members. Team members likewise shared information about water issues in the United States. Each team member had specific responsibilities for compiling notes on various topics. Individuals who are interested in more details are invited to directly contact individual members of the team as follows:

Frederick W. Crook	Chapters 1, 2, 7, and sources.
Xinshen Diao	Chapter 3, 8, and list of names.
Danny Goodwin	Chapter 4.
Dale Heermann	Chapter 5.
Vernon Schneider	Chapter 6.

The U.S.D. A. Water Team (hereafter referred to as the Team) is grateful and appreciates very much the Department of International Cooperation, Ministry of Agriculture for hosting the team. The Team also appreciated the warm welcome from the many offices visited at the Ministry of Water Conservancy.

In particular the Team acknowledges the support of Mr. Yu Shi-qiang who made the initial arrangements for the Team and provided excellent translations. The Team especially would like to thank Mr. Yu who accompanied the Team on all of its appointments and visits and did an especially good job of making sure the Team got on the correct airplanes, buses, and vans, and meetings on time.

The Team thanks the many hundreds of officials who graciously and warmly received us and openly shared their knowledge with us. The Team had many lively discussions with officials with whom we visited.

Please note that the numbers in this report were recorded as given to us by officials in China. They do not necessarily represent official USDA estimates or official estimates from China.

The U.S. Department of Agriculture, Foreign Agriculture Service, Economic Research Service, National Resource and Conservation Service, Agricultural Research Service, and the U.S. Geological Survey, the Ministry of Agriculture and the Ministry of Water Conservancy supported this trip. Ms. Suzanne Hale, Agricultural Counselor, and her excellent staff in the Agricultural Office, U.S. Embassy Beijing, provided support for this trip.

For each meeting or facility visited the Team tried to identify the name of the person interviewed, the persons' position in his organization unit and the name of the organization. The Team used China's pin-yin romanization system to designate Chinese names as follows: Wang Zhi-hong; Wang as the family name; and Zhi-hong as the given name.

Team members tried to clearly separate their evaluations and conclusions from what China's officials said during meetings. Typically this was done by writing statements such as "Mr. Wang Hao said" to indicate statements made by officials.

The Team used the term RMB to stand for China's currency Ren Min Bi (RMB) which at the time of our visit was convertible to US dollars at 8.2 RMB to US$ 1.

At various places in the report below Team members made references to published works. We used the form (M2, 1980) to indicate the specific reference at the end of the report.

Data and information in this report is as of the end of September 1999.

Objectives of the USDA Water Team

To meet with officials from the ministries and bureaus which are involved with water issues in China. The Team would like to know the function of the various institutions and to identify key water resource specialists in China with whom further research work can be continued.

To listen to officials and specialists to identify what they believe to be the most pressing water resource issues in China.

To collect publications and water resource data from the various institutions.

4. To exchange views with our counterparts in China as to what are the important water resource issues which the U.S. faces.

5. To identify with our counterparts from China topics of research projects, programs of work for future team exchanges and topics to be discussed in conferences of specialists.

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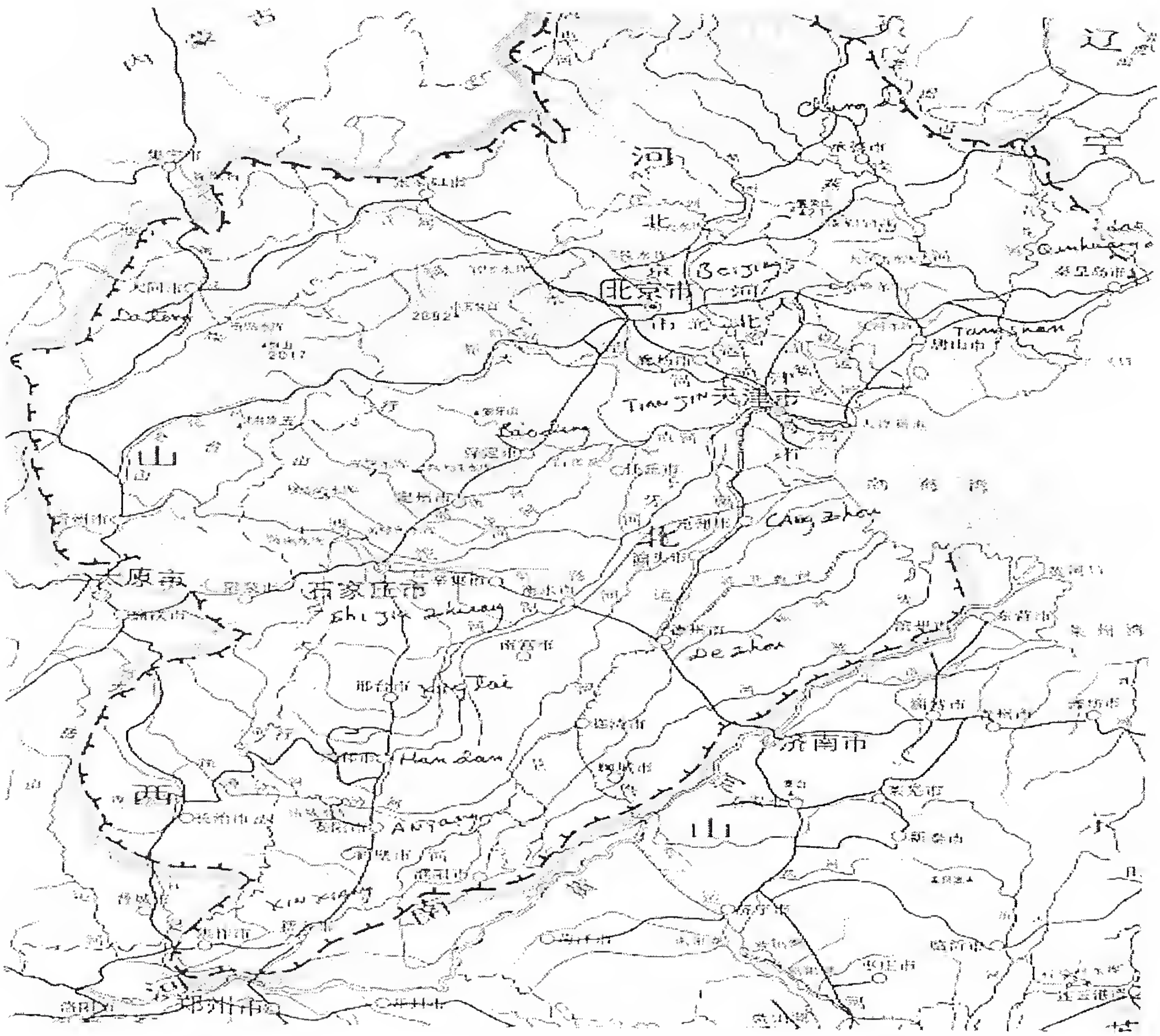
USDA Water Team Travel Routes in China

USDA Water Team Travel in the Hai Basin



Executive Summary of Important Findings

Water Resources: China ranks 5th in World

With 547 billion cubic meters of water in 1998. China ranked fifth in world water resources behind, Brazil, Russia, Canada, and Indonesia.

Water use in 1998 totaled 543.5 billion cubic meters.

Water consumption in 1998 was 306.2 billion cubic meters. Water actually consumed is lower than use because of leakage and inadequate management. Consumption to use ratios vary significantly by sector.

Agriculture	65.5%
Industry	24.7%
Urban domestic	26.1%
Rural domestic	87.7%
Average use	56.3%

Water Resource Conditions Vary Greatly Within China

Annual average precipitation decreases from 2,000 mm in south China to 600 mm in the north. From Shanghai's 800 mm in the east precipitation decreases to 200 mm near Wulumuqi in the far west in Xinjiang province.

Precipitation in China is not evenly spread throughout the year. Rather most rain falls during the months from May through September. Normally the months from October through April are relatively dry.

These precipitation patterns mean that some regions have surplus water and others are very dry.

China's Huge Population Is Unevenly Distributed

Most of China's 1.2 billion people live in the eastern one third of the country. The western two thirds of the nation is very sparsely populated.

In some regions like China's Pearl River there is a large population to go with heavy rainfall so per capita annual water consumption is over 600 cubic meters per person.

But in the heavily populated Hai basin which contains Beijing and Tianjin, rainfall is light and water resources are limited such that annual water consumption is 161 cubic meters in Tianjin and 201in Beijing.

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Table 2-1—China's major water basins

River Basin	Area	Annual stream runoff Total Volume	Percentage of national	Cultivated land	Population	Runoff Per ha	Runoff per capita
	1,000 Square Km	Cubic Km	percent	million hectares	million	cubic meter	cubic meter
Hai	319	28.3	1.0	11.3	92	2,505	308
Songhua	528	75.9	2.9	11.7	46	6,450	1,650
Liao	232	15.1	0.5	4.5	28	3,375	540
Huang	752	56.0	2.1	13.1	82	4,290	683
Huai	262	53.0	2.0	12.5	125	4,230	424
Chang	1,807	1,000.0	38.2	24.0	346	41,700	2,890
Zhu	415	307.0	11.7	4.4	74	69,750	4,150

Yao Bang-yi, p. 133.

Farms, Industry and Urban Areas Not Always Located Near Water Resources

Arable land is unevenly distributed in China mostly in the eastern one third of the country and is not always located near ample water resources. Officials selecting building sites for new industries sometimes did not pay attention to water supply and demand conditions. Sometimes urban areas developed without considering the water supply situation.

Managing the Country's Limited Water Supplies

The USDA Water Team believes that the officials we met at different levels of government, realize that the supply of water in China is limited.

The country is only water deficit in comparison with the situation in other countries. And of course within China's river basins some basins have more water than others. The primary problem is one of adequately managing China's scarce water resources.

Managing the Supply of Water

Officials cannot do much about the quantity and distribution of precipitation. But they have expended considerable efforts to build reservoirs to store water from the highly seasonal runoff. They also can better manage the over drafting of ground water resources which may not be recharging very rapidly in the short term.

Officials are engaged in moving water around river basins to try match supply with demand.

Growing Demand for Water Resources

In the past twenty years four major factors have boosted the demand for water supplies.

Rapid economic growth

Since 1980 China's economic growth rate has been outstanding. But this growth has had a major impact on water conditions. First, China's manufacturing sector grew by 12 percent annually during the last two decades. The demand for industrial use water has grown rapidly. Second, industrial users have become major polluters of water which renders water unusable for downstream users.

Urbanization

China's urban population has soared from 191 million in 1980 to 379 million in 1998. Urbanites tend to use more water than their rural cousins. For example in 1998 urban residents consumed an average of 222 liters per day compared with 87 liters in rural areas. This expansion of the urban population and their tendency to use more water has placed an additional demand on scarce water resources.

Food Grain Security

The current "governor's grain bag responsibility" places a high priority on expanding grain output for food grain security purposes. This impetuous has encouraged local officials to use water resources to increase grain production. At present China may not have a sustainable grain production system, i.e., the current levels of production are partly sustained through the use of surface and ground water resources. Some of these resources, such as ground water maybe declining as shallow and deep aquifers are drained which may leave decreasing quantities for future use. Also industry and urban units may be able to bid water away from agriculture as their demand increases.

If Demand for Water Is Greater Than Supply, Does This Fact Infer Shortages?

A number of studies published in China estimate water supply and demand and indicate that the gap between the two indicated shortages. For example Ren Hong-zun, "Wo guo que shui wen ti fen xi" (An Analysis of China's Water Deficits), in Liu Chang-ming, He Xi-wu, and Ren Hong-dao, Editors, Zhongguo Shui Wenti Yanjiu (A Study of China's Water Problems), Beijing, Qi xiang Chubanshe, January 1996, p.13-18.

If one only considers the quantity of water, then in a planned economy one can calculate water supply and demand. Min of Agriculture, Chen Yao-bang, says in the dryland farming book,

"China is a water deficit country." Ministry of Agriculture, Zhongguo Han qu Nongye de xi wang (Prospects of Dryland Farming in China), Beijing, Foreign Language Press, June 1999, preface.

From a market economy perspective, gaps between demand and supply are reflected in price changes. A decrease in supply could be reflected in a price increase, producers could take action to increase supply or if the situation persists users make alternative plans to use the higher priced water. In this sense then an estimated gap does not necessarily indicate a shortage.

Our conclusion therefore is that China does not have water deficits or water shortages but we do believe it does have significant water problems. Professor Wang Hao, "Analysis and Prospects of the Dynamic Trends in Water Resources in China," in Shen Zhen-rong and Su Ren-jing, Editors, Zhongguo Nongye Shui Wei-ji Duice Yanjiu (A Study China's Water Crisis), Beijing, Zhongguo Nongye Keji Chubanshe, December 1998, p. 12.

China's Agricultural Water Crisis

China's farmers and officials face a water crisis. Over the past decades farmers generally have not had to pay very much for the use of irrigation water.

But the water supply and demand situation is changing.

Supplies for irrigation water expected to decline

Generally it is believed that in the next few decades water supplies for irrigation will shrink.

In some areas there is less supply because farmers upstream are using the water. The lower reaches of the Yellow River is an example.

In some areas irrigation has stopped because cones of depression have appeared and irrigation wells dried up. Villages in Cangzhou, Hebei Province is an example of this condition.

In some areas waste water could be used for irrigation purposes but the water is too heavily polluted. Villages in Tianjin are examples.

In the competition for scarce water resources agricultural use water likely will not be able to out bid industrial and urban domestic use water. Industries and urban residents likely will have the financial resources to compete effectively with irrigation districts. These entities also likely will have more clout with political leaders that local irrigation districts.

The crisis is one primarily of a mind-set--farmers and local officials will have to get used to having less water. The country will not fall apart and the agricultural sector will not collapse. Nonetheless the agricultural sector will face some important problems.

Significant Problems To Be Faced

The Team saw that the supply of water used could be increased by careful planning and returning water used upstream back into channels for reuse down stream. Water which is now polluted could be cleaned up and reused down stream. Water managers can take measures to increase the efficiency of water use.

Since irrigation water is the single largest user of water in China, it is important to greatly increase the efficiency of irrigation systems.

Managers of China's water system and irrigation districts could implement programs to decrease the over drafting of aquifers and in preventing the pollution of existing aquifers.

The Team saw that through time farm families will adjust their cropping patterns to fit their particular water resource situation. Ministry of Agricultural, Extension System should provide guidance on introducing drought resistant varieties and methods to conserve and save water resources.

Chapter One

Chronology of Team Visit

Frederick W. Crook

Ministry of Agriculture

Morning MOA

On Monday morning, September 13 the Team met with Mr. Chen Zhi-wen, Deputy Division Director, Department of International Cooperation, Ministry of Agriculture and Ms. Gao Jing-hong, Senior Project Officer, from the same department. Mr. Chen reported that the Ministry of Agriculture (MOA) is interested in the following topics: long term agricultural sustainability, food security, environmental pollution, water management, water quality, and the rehabilitation of degraded environment. MOA is interested in cooperation with regard to water management, water basin management, the monitoring of water, and water saving technology.

Frederick W. Crook, USDA Water Team Leader explained the background for this visit. In December 1997 at the joint USDA/MOA meetings in Washington DC both sides agreed that for the next four years the two sides would focus effort on water problems, irrigation and irrigation efficiency and at the end of the fourth year a conference of participants would be held to summarize experience. In 1998 the two sides were not able to put together their respective water teams in time so this 1999 USDA water team is the first team to come to China. The second round of teams should be discussed in the next joint meeting to be held in late 1999.

Also on Monday morning we met with Mr. Guo Zuo-yu, Deputy General Director, Information Center and Mr. Li Bing. Mr. Guo once was a production team leader in Zhumadian, Henan province. Mr. Guo reported that water issues are very important in China's economic development. Mr. Guo noted the MOA is concerned about growing water shortages in China. In 1999 MOA initiated the "dryland crop program (see Chapter 2). Mr. Guo gave the Team four publications. First he gave us several copies of Ministry of Agriculture, Prospects of Dryland Farming in China, Foreign Language Press, Beijing, February 1999. Second, Ministry of Agriculture, Zhongguo han zuo jie shui nong ye guan li xin xi xi tong (An Introduction to China's Information System for Management of China's Dryland Crops and Water Management. Third, a brochure, Ministry of Agriculture, "The Information Center of the Ministry of Agriculture." Fourth, a brochure "China's Agriculture Information Network." Mr. Li Bing gave a short briefing on the Information Center's role in dealing with water issues (see Chapter 2).

Mr. Xie Jian-min, Division Chief, Development Planning Department, reported that the list of questions for his department went to another officer and he did not receive the questions. He said one of the important priorities for his department is the dryland-

farming program. He believes that the demand for water will go up because of the growth of industry and the increasing population, water transfers will be costly. There will be water shortages. From an invest perspective it may be cheaper to invest resources in dry land farming than in water transfers. A team member asked Mr. Xie regarding what types of things his department would like to cooperate. He said crop cultivation techniques, mechanization, bio-tech to breed drought resistance into crops, sustainable agriculture and demonstration bases (see Chapter 2 and 3 for details.

Afternoon MOA

On Monday afternoon we met with Mr. Zhu Yu, Deputy Director, Production Materials Division, Crop Production Department. Mr. Zhu attended the Tucson meetings in April. He said the Ministry of Water Resources (see Chapter 2 and 3) should answer many of the questions we asked him.

Also on Monday afternoon we met with Mr. Pan Xue-feng, from the Department of Agricultural Mechanization. We think he earned a Ph.D. in agricultural engineering.

Morning MOWR

On Tuesday morning, September 14 we met with Mr. Feng Guang-zhi, Deputy Director-General, Department of Rural Water Conservancy, Ministry of Water Resources (MOWR); and Mr. Zhang Han-song, Division Chief, Division of Engineering Consulting, MOWR. Some of the Team members met Mr. Feng at the meetings in Tucson; in fact he was a co-panel chair with Dale Heermann. The Team spent more than 2 hours with Mr. Feng who gave a general overview of the organization and functions of MOWR and then talked more specifically about his own department (see chapter 2 and 3). He gave the Team some of his notes and two books: Chen Yu-min, et.al. Editors, Zhongguo zhuyao zuowu xushuiliang yu guangai (China's Important Crop Water Requirements and Irrigation), Beijing, Shuilidianli chubanshe, Feb. 1992; and Ministry of Water Resources, Zhongguo shuili nianjian, 1998 (China's Water Yearbook, 1998), December 1998

Mr. Feng has been with MOWR for an extended period of time and is very knowledgeable about the work of his ministry. If one wants to learn about water issues in China, he is a very valuable person to meet.

After the discussion we walked to the MOWR bookstore and purchased an armload of books on China's water issues. Mr. Feng showed us a yearend statement about water resources, which was published in Shuili Bao (Water Conservancy News). Later we obtained a copy from MOWR.

Afternoon MOWR

On Tuesday afternoon the Team met with Mr. Niu Chong-huan, Division Chief, Planning Division, Department of Soil and Water Conservation, and Mr. Li of the same division who is responsible for remote sensing for his department. Members of the Team also met

Mr. Niu during the Tucson meetings. He gave each Team member a book entitled, Ministry of Water Resources, Soil and Water Conservation Department, Zhongguo qi da liu yu shui tu bao chi gong cheng jian she.(Soil and Water Conservation Projects in China's Seven Large Basins), Beijing.

During our meetings with MOWR officers we learned that the Bureau of Hydrology which now has become a research institute which is attached to the ministry performs some important functions and collects data about China's underground water situation.

MOWR Field Trip To Tong County, Beijing

On Wednesday September 15th the Team drove from Beijing to Tong County. We met with Mr. Sun Feng-hua, Water Bureau, Beijing Municipality. We believe Mr. Sun was trained in hydrology, spent one year in Italy and earned a MBA in Holland. Mr. Sun accompanied us to Tong County Water Bureau whcre we met Mr. Jin Jian-hua. He accompanied us to visit some irrigation facilities in Xu Xin Town.

From Xu Xin Town we drove north to Mi Yun Reservoir where we met Mr. Zhang De-ju, Vice Director, Management Division, Mi Yun Reservoir, Beijing Municipality. After lunch and a briefing at a reception center we drove to see the dam and reservoir. Note that whereas a few years ago we were able to drive across the dam and wander around he reservoir, now the area is closed to the public. Mr. Sun said that the area was closed because of the increasingly serious water shortages in Beijing and the increasing sensitivity of officials to keeping Beijing main source of water safe.

Morning Chinese Academy of Agricultural Sciences (CAAS)

On Thursday, September 16th the Team met with researchers from different institutes which belong to CAAS. Professor Mei Xu-rong, Deputy Director General of the Institute of Agrometeorology. Members of the Team met him at the meetings in Tucson. Dr. Mei received the list of question prepared by the Team and designated specific persons to respond to specific questions. He organized the presentations.

Ms. Wang Jin-xia, represented Professor Huang Ji-kun, from the Institute of Agricultural Economics--he was in Holland attending some meetings. She gave a presentation about the research work her institute is engaged in on water issues. She plans to go the University of California, Davis for her post-doctoral work.

Mr. Xu Tao just returned from VA Tech where he completed a dissertation on China's water policies regarding industrial pollution.

Mr. Li Jiu-sheng works on irrigation and sprinkler type irrigation problems.

Mr. Qi Xue-bing, is a director of the Farmland Irrigation Research Institute, located in Xin-xiang Prefecture, Henan province.

Dr. Yan Chang-nong, works on agricultural ecology and water cycles. He gave the Team a copy of his notes on water requirements for China's major crops (see Chaper 2).

Dr. Sun Cheng-fu, works on green house issues.

Luo Yuan-pu works on water projects.

Ju Hui, works on agronomy

Ms. Lu Xiu-ling works on water conservancy issues.

The Team had a robust discussion with CAAS members, (see Chapter 2 for details).

Afternoon, CAAS Experimental Plots

In the afternoon, Professor Mei led the Team to visit one of his test plots where his staff was evaluating a dripsystem used in green houses.

Later in the afternoon we visited with Ms. Zhang Lin-xiu, Deputy Director General, Institute of Agricultural Economics and Ms. Wang Jia-xia.

Morning Chinese Academy of Science (CAS)
Institute of Geography

On Friday September 17th the Team met with staff from the Institute of Geography. Professor Liu Yi reported that the institute this year is 59 years old. Currently they have a staff of 400 people. The Institute has three parts: natural geography, human geography, and geo-systems research (GIS). They have some 200 research projects: about 33 percent of the projects come from the National Key Projects, about 33 percent come from China's National Science Foundation, and about 33 percent of the projects come from local provinces (counties) and from foreign entities.

Professor Li Li-jian, Deputy Director of The United Research Center for Water Problems used a power point presentation to introduce the Team to her center. (See chapter 2 and 3).

Professor Liu Chang-ming, Director of the United Research Center for Water Problems (he has a host of other titles including Editor of Acta Geographica Sinica, also used a power point graphics package to brief the Team on underground water in the north China plain. Four members of the Team participated in the Tucson conference with Professor Liu.

Professor Kang Yao-hu, gave a presentation on the Yucheng comprehensive experimental station (see chapter 2 and 5). Professor Xie Xian-qun, Director of the station also gave a presentation.

Afternoon, China Institute of Water Resources and Hydropower

On Friday afternoon, September 17, 1999 the Team met with Professor Wang Hao, Division of Water Resources. Professor Wang attended the Millenium Conference on China's rural economy in 1997 where some Team members met him. There are 40 persons working in his division. Wang has worked on China's water issues for a long time and is knowledgeable about the issues.

In the afternoon the Team met with Professor Li Yi-nong, who works in Irrigation and Drainage Division of the Institute. There are 33 staff members in his division. Professor Li and Dale Heermann have a mutual friend, Luis Santos Pereira who is an irrigation specialist from Lisbon, Portugal.

From the Institute the Team went to the Agricultural Office, US Embassy to visit with the officers there.

Travel to Tianjin

On Saturday morning, September 18, 1999, the Team traveled by car from Beijing about 100 kilometer southeast to the Municipality of Tianjin (a municipality has the same administrative rank as a province). Our MOA host put us up in the Tianjin Keji Daxia (Interotel). The Team had no formal meetings this day but did have an informal Team meeting to digest and summarize what had been observed and discussed in the many meetings during the past week.

Travel to Ji County

The Team boarded a big Dodge van around 7:45 am and traveled about 100 kilometers north to the most northern county in the municipality. The suburbs surrounding Tianjin are heavily industrialized and we had to travel a considerable distance before we saw grain fields.

Water Ways

On this trip we crossed many natural and man made waterways which carry water and sewage across the plain to the Yellow Sea. We crossed the New Yong Ding River, which we think was constructed as a flood prevention facility. We also crossed the Bei Yun He which is the Grand Canal which were we told was constructed during the Sui dynasty (600 AD). Later on in the trip we crossed the Chao Bai River. Also we crossed one waterway which our hosts from Tianjin said was a sewage canal.

Crops

Corn was the main standing crop on this trip. Hand harvesting has begun. Most of he irrigated corn looked very good. But we also some fields in which the growth was only 3 to 4 feet high. In the rain fed mountainous area where farmers had planted corn on hillside terraces, the crop was stunted and dry. A local farmer we visited with said that for two months no rain fell...his irrigated crops did well. The Team also saw many vegetable fields and large areas of greenhouses. The Team saw only a few japonica rice fields, a few lotus paddies, and patches of soybeans and sunflowers. Farmers also had small patches of cotton--often close to their farmsteads.

Farmers in the area also have many orchards: apple, pear, persimmon, and walnut. Individual farm families were selling the produce along the roadside and fruit consolidators were buying produce and loading the fruit into small trucks headed for wholesale markets.

Grain Storage Bins

On the way to Ji County the Team saw some galvanized sheet metal bins for sale in some of the villages and town. We speculated on what these bins could be used for. On the return trip we stopped and examined the bins. The sign on the bins said they were for grain storage and could be purchased at a certain location near the local train station. The bin was about one meter in diameter and about two meters high. One of our Tianjin hosts from the agricultural section said the bins could store about a ton of grain and cost RMB 140. (See photograph 1-3).

Feed Mills and Aquaculture

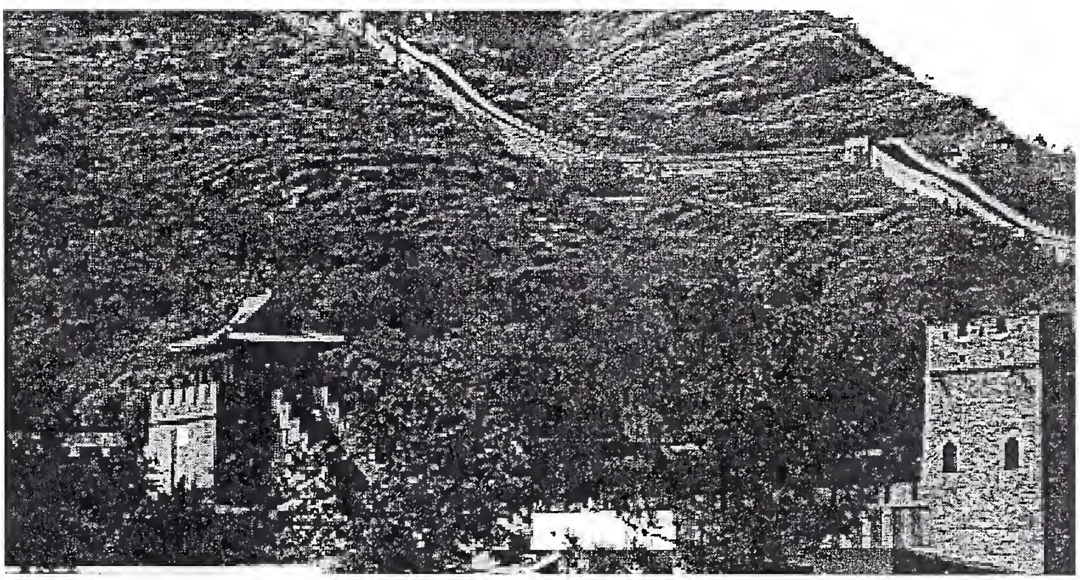
We saw a few big feed mills and many signs advertising feed painted on village walls. The area we passed through had some swampy areas which had fish ponds and it looked like farmers made fish ponds from the borrow pits along roads. Certainly the pits were dug out to raise the road level above the land...but did the holes fill up with ground water or did farmers use surface runoff or canal water to fill the ponds. Advertisements for feed for fish were also on the village walls.

The Great Wall of China at Huang Yu Guan

The end of our destination was the Great Wall of China at Huang Yu Guan. The Wall at this place is spectacular. The wall comes in from the east descends into a narrow valley with a stream at the bottom and then proceeds up the slope on the west. They hills were green with vegetation and there were pine trees on the slopes. Farmers in the valley tend persimmon, almond, hazel and walnut trees.

Photograph 1-1 Metal grain bin for sale to farm households

Photograph 1-2--Great Wall of China at Huang Ya Guan



Morning Tianjin Ag Bureau

On Monday morning, September 20, 1999, the Team met with officials from the Tianjin Bureau of Agriculture and Forestry. Mr. Zhang Jie, Deputy Director of the Bureau, organized the speakers from the China side. Mr. Zhang gave a brief introduction about agriculture in the municipality. Mr. Zhang Jin-jiang, 75 years old, briefed the Team on rice production in the city. Mr. Zhang Yi-lin gave a briefing on corn production in the city and Mr. Yao Zhen-fan followed with a discussion about wheat production.

Afternoon Tianjin Water Conservancy

On Monday afternoon, September 20, 1999, the Team met with two officials from the Bureau of Water Conservancy, Ms. Tian Ping-fen, Director of Office of Management of Water Resources, and Mr. Yang Hui-dong, from the office of Rural Irrigation. Ms. Ma Xiu-qing, Senior Engineer, represented the Haihe River Water Conservancy Commission, Ministry of Water Resources. Ms. Ma gave the Team a 32 page brochure entitled "Haihe." Also she gave us a copy of a paper she wrote with Li Yan-dong, Department of Planning and Scientific Research, Haihe River Water Conservancy Commission, "The Influence of Deficiency of Water Resources in the Haihe River Basin of Social Economic Environment and Its Countermeasures," September 1999, 8 pages.

Field Trip to He Wu Xi Town and Xin Kou Town

On Tuesday morning, September 21, 1999, the Team drove northwest from Tianjin to Wuqing county and then on to He Wu Xi Town.

Water Ways

On this 60-kilometer trip we crossed a number of waterways. One was a sewage waterway, which carries sewage from Beijing, through Tianjin to the sea. We also crossed the Bei Yun he or the Grand Canal. We saw many ditches and canals as we traveled through the areas. There is a maze of water channels. Team experts believe siphons are used so that wastewater does not contaminate fresher water when the channels cross.

Corn Crop

The predominant standing crop in the area was corn. Some stands looked good but many plants were 3 to 4 feet high. In one field we checked the cobs and they were short and not well filled out. Farmers had just begun to harvest the corn.

Other Crops

Other crops observed along the way were sorghum, sunflowers, peanuts, cotton, apple and pear orchards, and many vegetable fields.

Rural Advertising

The Team saw many ads written on village walls and building.

- Animal feed
- Fish feed
- Support the birth control policy
- Offers to dig irrigation wells (see Photograph 1-3).

Trip from Tianjin to Beijing Airport

On Wednesday morning, September 22, the Team drove from Tianjin to the airport in Beijing a distance of about 120 kilometers.

Corn Crop Stunted

A great many stands of corn along the way were stunted by the drought during July and August and in many of the fields the stalks were 3 to 4 feet high. Some of the stands had dried out. Irrigated corn fields were green and the stalks at a normal height. Farmers were harvesting their corn crop and a few fields had been prepared to plant winter wheat.

Salinity Problems

Along the way we saw large fields of sunflowers which meant to us that some of the fields has salinity problems. One can see the same kind of situation on saline soils along the western edge of the Songliao plain (Baicheng, Jilin province). We also saw wide variation in corn stands in those fields so that some corn looked very good and then a few feet away one could see a very poor stand.

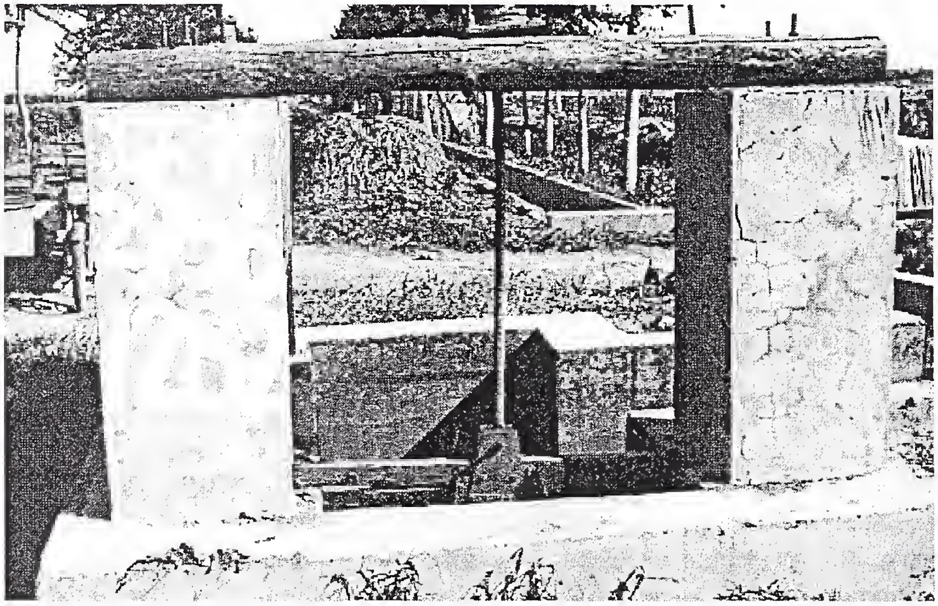
Rice Harvesting Underway

In the outskirts of Beijing farmers were harvesting japonica rice. The fields were still green and farmers were laying the shocks of rice on the field to dry. We did see one machine on a 12 horsepower tractor cutting the rice stalks down. We wondered why the farmers were so anxious to clear the fields of the rice crop. Could it be that these fields also would be planted to winter wheat?

Trip from Xian Airport to the Qin Tomb and Hotel

On Wednesday afternoon, September 22, the Team drove about 60 kilometers from the Xian airport around the city and onto the Qin tomb. The Team stayed in the Xian Sheraton Hotel.

Photograph 1-3--Well driller's advertisement and telephone number



Photograph 1-4—Well drilling rig in operation near Xian, Shaanxi province

Corn

Corn was the predominant standing crop and farmers were busy in the fields harvesting the cobs and cutting down the stalks. Farm families piled cobs on walls or hung the cobs in bundles on trees to dry. We saw mostly women in courtyards shucking the ears of corn picked by men in the fields. It looked like most of the corn was picked by hand. We did see one man shelling an ear of corn by hand. The cobs we saw were long and well developed. The farmhouses had a very colorful look all capped with golden corncobs.

Orchards

The Team traveled through large areas of orchards. Most of the stands we saw were apple trees but we also saw peach, and pomegranate trees. Farm families were selling their apples and pomegranates along the roadsides.

Also we were surprised to see farmers selling kiwi fruit. We had not seen the plants but were told that the fruit grows on a bush type plant in what looked like grape vineyards to us.

Morning Shaanxi Agriculture Bureau

On Thursday September 23, 1999, the Team met with Mr. Gao Yuan-xiong, Foreign Affairs and Trade Division, and Mr. Lu Xi-jing, Agricultural Production Division, both from the provincial Agriculture Bureau. Before the Team assembled Mr. Gao said that the dust in the air around the city of Xian comes from the deserts from the north and west. He said the dust settles on plant leaves and has some negative effect on crop production. We also wondered if the dust reduces the solar energy reaching the ground and in some way interferes with photosynthesis.

Afternoon Shaanxi Water Bureau

On Thursday afternoon, September 23, 1999, the Team met with Mr. Liu An-qiang and Mr. Tang So-ren, both from the Shaanxi Water Conservancy Bureau. The bureau received the questions prepared by the Team and Mr. Liu had prepared a handout of data and answers to questions. The briefing went very well.

Afternoon Yellow River Commission--Middle Reaches

After the briefing by the Water Bureau Mr. Han Min and Mr. Jiang Xiao-qin from the Yellow River Commission--Middle Reach Bureau briefed the Team. See chapter 3 for details.

Morning and Afternoon Field Trip

On Friday morning the Team drove about 60 kilometers north to the Jing hui Irrigation District located in San Yuan County. On the way we crossed the Wei and Jing rivers. See chapter two for details about the district. From San yuan we drove perhaps 30 more kilometers over a very poor road to the dam on the Jing river. We then returned to San yuan, had lunch and then drove about 10 kilometers north to Yu gou nao village, which is located on the loess plateau.

Corn Is the Main Crop

Corn is the main standing crop along the route we traveled. Farmers were harvesting the ears of corn, and stacking them in their courtyards. We saw both male and female workers shucking the husks off the ears. Farmers were using the edges of the roads to dry the shelled corn. We saw several teams working to shell the corn. It looked like enterprising farmers had hooked a small shelling machine to their tractors and were doing contract work. Farm families pushed the cobs into the throat of the machine. The sheller crushed some of the cobs so that farmers had to sift out the broken cobs from the grain.

We also saw many farmers piling corn stalks on carts, which they were taking to their homestead. There were piles on stalks around the farmhouses. We also saw that some farmers were burning the husks.

Winter Wheat Seedbeds Being Prepared

Most of the corn has not been harvested yet, but we did see some fields, which were being prepared for seeding winter wheat. We saw many small and large wheel tractors with rotor-tillers attached on their way to and from tilling up the corn fields.

Orchards

Apple, peach, and date orchards were prevalent in the area. We saw farmers boxing up apples in standard, pre-printed boxes (Xian Apples). Later we saw several big trucks carrying apples to market.

Well Drilling

On the way the Team saw a well drilling rig and on the way back to Xian we had the driver stop and we took photographs. See Photograph 1-4.

Vegetable Wholesale Markets

In several of the county seats and in some township seats we saw large shed type markets for vegetables and fruits. It may be that it is a wholesale market so that farmers bring in their produce and consolidators make up a truck load to take to Xian or other cities.

Village Advertisements

Probably the most common wall posters were urging people to follow the family planning guidelines and have fewer children. Other signs included the populace to protect land and water resources, and support the education of children.

The Road Tax

In one village men were stopping trucks and were extracting a tax to help construct a new road through the village. The villagers did not stop the escorting neither police car in front of us nor the vehicle we were riding in.

Visit to the Zhang Family, Yu Gou Nao Village

The Zhang family lives on the edge of the loess plateau and their house is built into the side of a wall of loess. Mr. Zhang is a demonstration farmer and as such receives some government assistance.

Dates

Mr. Zhang showed us the technique of grafting a high yielding date on a wild date root. The fruit from these trees are large and delicious. The extension agent said that farmers who adopt this technology could increase per capita income by 200 RMB. The wild date is a hardy plant, which is able to find moisture--it spreads through underground roots.

Cistern in Use

The family collects water run-off and channels it into a cistern in their farmstead. Mrs. Zhang showed us how to use the homemade winch to draw water from the well. See Photograph 1-5--The Zhang family's cistern.

House Built into the Hill

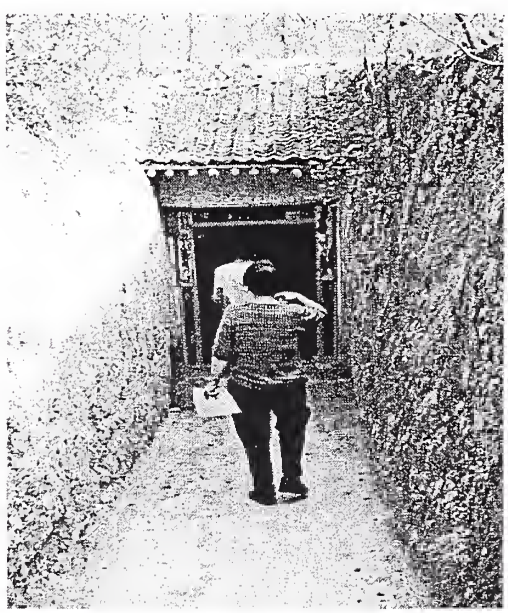
The Zhang's house is built into the hill. There is a small courtyard, two bedrooms, a kitchen, and some storage spaces for farm equipment. See Photograph 1-6—Loess plateau cave dwelling.

Terraced Fields

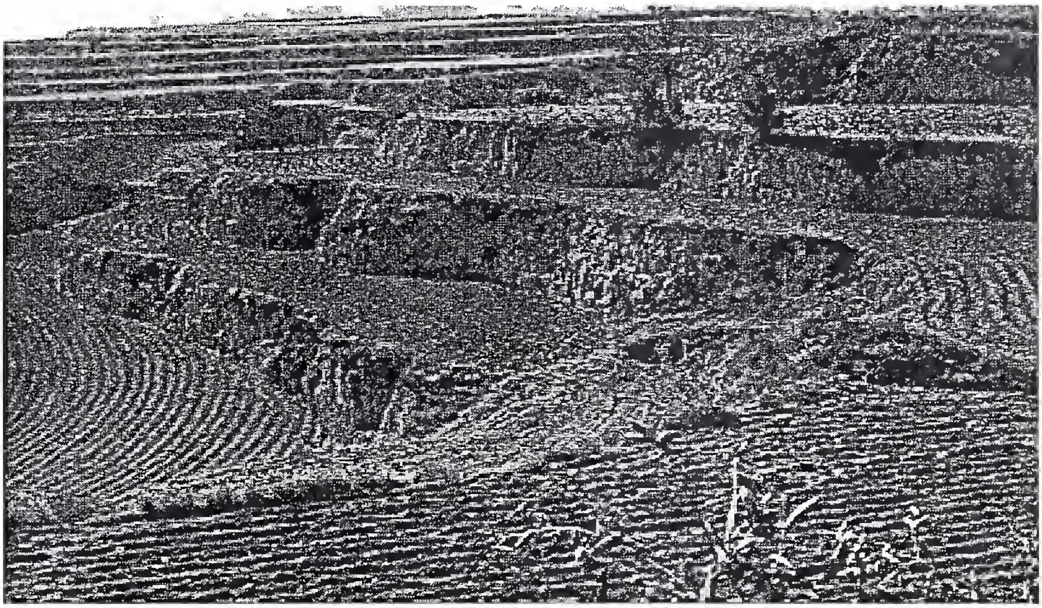
From Mr. Zhang's house one could see terraced fields in all directions. The fields near his house and the terraces looked like they were in good shape but further away the terrace edges looked more ragged. A local cadre said they have the situation only partly under control. See Photograph 1-7—Terraced fields in China's loess region. On the way down to the valley floor we passed some fields in which the terraces had been widened by the use of heavy equipment.

Photograph 1-5--The Zhang family's cistern.

Photograph 1-6--The Zhang family's loess cave dwelling



Photograph 1-7--Terraced fields in China's loess region.



Photograph 1-8—Karez (underground tunnel) irrigation system in Xinjiang

Team Flew from Xian to Beijing

On Saturday, September 25 the Team flew from Xian to Beijing and back into the Beijing New Asia Hotel. On Sunday, September 26, Dale Heermann and Danny Goodwin returned to US, and Vernon Schneider returned on Monday, September 27th.

MOWR, Department of Water Resources

On Monday September 27th, Frederick Crook and Diao Xin-shen met with Mr. Chen Ming, who is the Director of the Water Saving Division, Department of Water Resources. Mr. Chen reported that the Department of Water Resources has responsibility for policy and planning of water resources while the Bureau of Hydrology has responsibility for managing the hydrology stations and for measuring surface and ground water. Mr. Chen did give us a copy of the "1998 Zhongguo Shuili Ziyuan Nian Bao," and "1997 Zhongguo Shuili Ziyuan Nianbao." We would like to thank Mr. Yu Shi-qiang, MOA, for making this important appointment for us.

Travel in Xinjiang Province

On Monday October 4th, Frederick Crook drove from Wulumuqi, the capital of Xinjiang province southeast to the Tu-er-pan basin. Farms in the basin obtain their water from melted snow water from the Tianshan mountains to the south. The landscape we drove through reminded me of similar scenes from Nevada. In some place the wind has completely blown away the soil leaving what looks like gravel and stones (ge bi).

Wind Powered Electric Generators

Between Wulumuqi and Tuerfan we saw hundreds of very large 3 bladed props on pylons spinning away generating electricity. There were rows and rows to the machines and new towers were under construction.

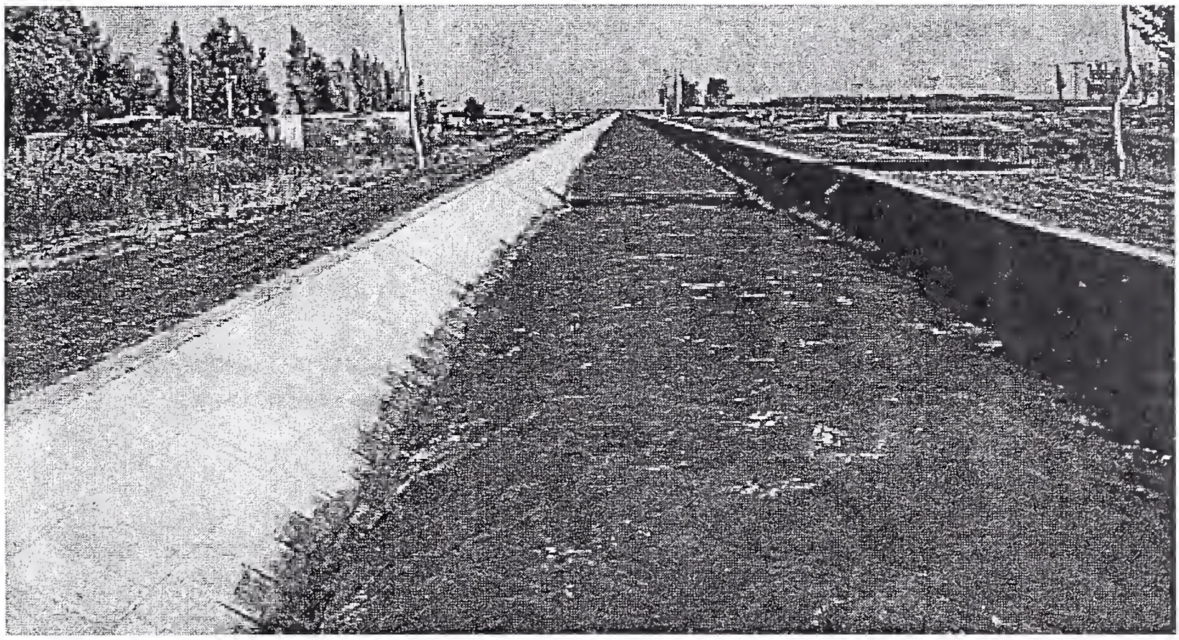
Grapes in Tuerfan

In Tuerfan we visited several vineyards. The vines are on trellis systems. The grapes had been harvested and farmers were drying their grapes in specially constructed drying houses. The walls of the houses are made of adobe bricks and bricks are left out so that the air can circulate through the walls.

Karez Irrigation

In Tuerfan we saw a demonstration of karez type irrigation. Farmers tunnels far beneath the surface of the land to lead water from rivers and springs to their fields. We were told that the karez system is very old and continues to be used. From what we could see the ditches were made of dirt and not cement so there could be some loss through seepage

Photograph 1-9—Concrete lined ditches in Xinjiang province.



Photograph 1-10—Sprinkler irrigation system in Xinjiang province.

but the underground tunnels likely would cut down on evaporation. We were told that the province has thousands of kilometers of these tunnel systems (see Photograph 1-8—Karez [underground tunnel] irrigation system in Xinjiang).

Surface Irrigation

On the way back to Wulumuqi we took an alternative route to To-ke-sun county and observed surface flood irrigation in progress. The ditches were lined with concrete. (See Photograph 1-9—Concrete lined ditches in Xinjiang province.

Travel in Xinjiang to State Farm Number 106

On Tuesday, October 5th Frederick Crook traveled northwest from Wulumuqi to State Farm Number 106. We believe it was the last stop before the desert.

Canal Irrigation System

As was the case for Tuerfan water from the snow capped Tianshan mountains to the south is captured and led through gravity flow out into the desert. The canals we saw were quite large and were concrete lined (See Photograph 1-9). The lateral ditches seemed also to be concrete lined. We also saw tube wells in the area but could not tell what proportion of water came from canals and wells.

Spray Irrigation System

As we neared the end of the road we saw that farmers were using metal irrigation pipelines to pump water to spray stands. See Photograph 1-10—Sprinkler irrigation system in Xinjiang province. They were irrigating winter wheat.

Alkali Soils

As far was we could tell alkali is a big problem in the area. In some areas the ground was white with alkali salts and one could see salt on the borders of fields. It looks like state farms are trying to reclaim these lands by flushing the salt out with fresh water and draining the salt away in drain ditches. Another indication of the salt problem is that farmers are growing large fields of sunflowers, which have some tolerance to alkali. Finally the crop growth is spotty in the fields. In areas where the salt concentrations are low the crops look good but 10 feet away they look poor. The area looks very similar to areas in the Newlands project in Nevada.

Cotton Fields

In the area we traveled through there were very large fields of cotton. Workers were in the fields picking the cotton by hand. The primary field activity on this day was picking

cotton. While we stopped for a rest 6 to 8 large tour buses passed going towards Wulumuqi. The driver said the buses were filled with young women from Shandong and Henan who were hired to come out to Xinjiang to pick cotton.

Farmers picked the cotton by hand and put the bolls into a sack. The cotton was then collected at the end of the rows and put into large bags. In a number of cases we saw workers spreading the bolls on canvas ground cloths.

We saw a great number of tractor drawn wagons full of cotton on the way to the purchase depot. When we go to the end of the road wagons were lined up for several kilometers waiting for their turn to enter the depot.

Sugar Beets

State farms in the area have quite large fields of sugar beets. We saw a few fields where the beets had been dug up and put in piles to be transported later to the mill. We saw one sugar mill not to many kilometers outside of Wulumuqi. Next door to the sugar mill there is a Sino-Italian ketchup mill--we could see the big trucks loaded with fresh tomatoes.

Travel in the Hai Basin

On Saturday, October 9, Frederick Crook and Mr. Sun, Agricultural Office, US Embassy traveled about 530 kilometers from Beijing southeast to Tianjin, and then south to Cangzhou, then west to Baoding, and then northeast back to Beijing. For details on water issues see Chapter 7.

Corn Crop Stressed by Low Precipitation in July and August

The irrigated corn in Beijing and Tianjin has been mostly harvested and winter wheat has been planted. But in the Cangzhou area farmers were still harvesting their corn crop. In many areas the corn stalks were only 2 to 3 feet high. In a number of fields we checked and found many of the stalks had no cobs.

The farmers who talked to us about the yields said that no rain fell in July and August and many of the stalks had no cobs.

On the other hand the corn on the west side of the plain, i.e. the area which has better water resources next to the run off areas from the mountains looked very good. In my many times down that stretch of road the corn in the fall usually always looks good.

I recommend that when crop assessments are made of the north China plain that one drives south through Baoding and Shijiazhuang and then at some point turn east to go across the plain towards the Yellow Sea and then back up the coast to Beijing.

Planting and Irrigating Winter Wheat

The main field activity was preparing ground for seeding winter wheat. We saw a wide variety of tillage methods: men using hoes, one mule drawing a small moldboard plow, a team of mules with a plow, a 15 horsepower tractor with a two bottom plow with disc attached, a 15 horsepower tractor with a small roto-tiller, a large wheel tractor with a 2 to 3 meter wide roto-tiller, and finally a large crawler tractor drawing a 6 bottom plow.

There were likewise a variety of seeding machines: hand drawn two-row seeder; but the most common was a 2-meter wide seeder drawn by a 15 horsepower tractor. One farmer told us his tractor cost 7,000 RMB and the seeder 1,000 RMB.

Farmers were using stationary small diesel engines or the flywheels of their tractor engines to drive their pumps.

Travel in Beijing

During a weeks stay in the city of Beijing the Team saw evidence of attempts to plant grass, trees, shrubs, and flowers along roadways, parks, and highway interchanges. Officials also reported to the Team that a small but growing category of water use is for urban environmental use.

Also the Team saw TV advertisements urging residents to take water saving measures. Bill boards along streets urged residents to conserve water and to treasure water as an important resource (see Photograph 1-11)

Photograph 1-11—Save water bill board in Beijing.

Chapter Two

China's Institutions Involved with Water Issues: A Brief Introduction

Major Water Basins

Before launching into a discussion of institutions in China which are involved with water issues, we thought it expedient to provide some basic data on the major water basin and also present a map which gives the location of the various basins.

Table 2-1—China's major water basins

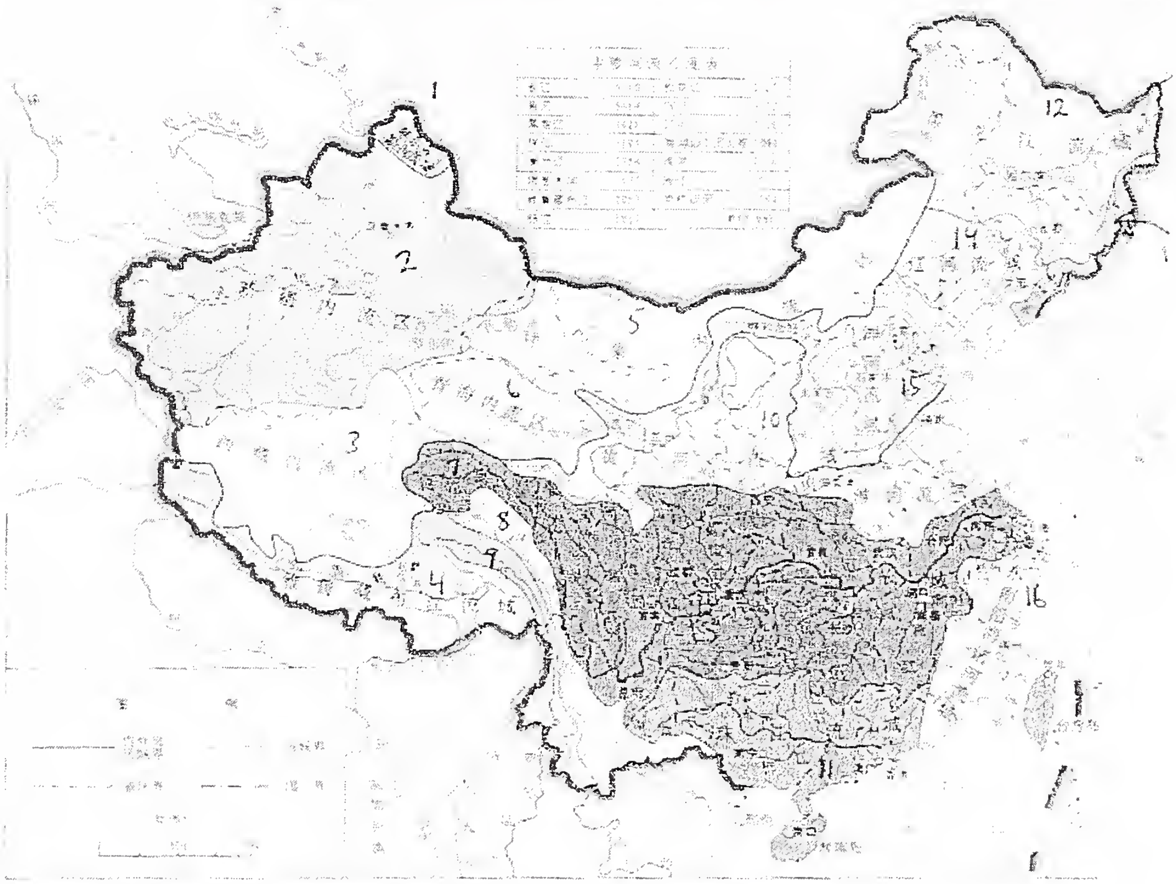
River Basin	Area	Annual stream runoff Total Volume	Percentage of national	Cultivated land	Population	Runoff Per ha	Runoff per capita
	1,000 Square Km	Cubic Km	percent	million hectares	million	cubic meter	cubic meter
Hai	319	28.3	1.0	11.3	92	2,505	308
Songhua	528	75.9	2.9	11.7	46	6,450	1,650
Liao	232	15.1	0.5	4.5	28	3,375	540
Huang	752	56.0	2.1	13.1	82	4,290	683
Huai	262	53.0	2.0	12.5	125	4,230	424
Chang	1,807	1,000.0	38.2	24.0	346	41,700	2,890
Zhu	415	307.0	11.7	4.4	74	69,750	4,150

Yao Bang-yi, p. 133.

The Qinghai-Tibetan plateau gives rise to many of China's great rivers: the Yellow, the Yangzi, the Mekong, the Irrawady, the Salween and the Brahmaputra. In Table 2-1 above the last four on the list have been left out of the table. Likely these rivers have been left out of the table because while the head waters are in Tibet little of the water which flows in these rivers in China can effectively be used in China.

Figure 2-1—China's water basins.

图1-1 中国主要江河分布概图



本图上中国国界线系按照中国地图出版社1989年出版的1：400万《中华人民共和国地形图》绘制。

Ministry of Water Resources Hydrology Department, Wang Jin-sheng, Editor, Zhongguo Shui Wen Zhi (A Compendium Of China's Hydrology), Zhongguo Shuili Shuidian Chubanshe, Beijing, December 1997, p. 28

1	E er ji basin
2	Xinjiang drainage
3	Xizang drainage
4	Ya lu zang bu
5	Gan-meng
6	Qinghai drainage
7	Yangzi
8	Lancang
9	Nu
10	Yellow
11	Pearl
12	Heilongjiang
13	Yalu
14	Liao
15	Hai
16	Southeast coastal

Ministry of Agriculture

Information Center

Mr. Li Bing reported that his center provides some water related information to high policy makers and puts up data and analysis on an information computer network which can be accessed by units at national, provincial, prefecture, county, and even perhaps at township levels.

The center maintains a historical weather data base with 1968 as the first year in the series. Data contained in the data base includes: precipitation, temperatures, relative humidity, and some data on soil moisture. Each day the current daily weather data comes into the center by computer from the National Weather Bureau. Also the center uses U.S. satellite imagery to keep current on the agricultural situation in China. Mr. Li showed the team some examples of their work: a) a map showing accumulated precipitation throughout the country; b) areas which had been flooded in the Yangzi river last year; and c) a map which showed a vegetative index of the greening up of winter wheat in Anhui province in 1999. Mr. Li gave the Team two brochures explaining the functions of the center and the computer net work they operate.

Department of Development and Planning (Fazhan jihua si)

Mr. Xie Jian-min, said that the Ministry of Water Resources (MOWR) is responsible for providing water to about half of China's arable land and the Ministry of Agriculture (MOA) is responsible for the other half (rain fed agriculture).

His main point was that China will encounter increasingly severe water shortages, the demand will greatly outpace supplies, the agricultural sector likely will be allocated less and less water each year. From an investment point of view it is very costly to build water transfer projects...it is cheaper to invest in dryland farming projects.

In 1996 MOA established some bases to demonstrate the advantages of dryland farming. The investment in the last few years has been about 20 million RMB.

Minister of Agriculture, Mr. Chen Yao-bang stated in his preface to MOA's book on Prospects of Dryland Farming in China , noted that the program had four aims:

- to establish a fundamental grain security system in a bid to ensure that the amount of high and stable farmland per capita is 1 to 2 mu
- grain output per mu is over 300 kilograms
- the annual per capita grain ration is no less than 300 kilograms
- to develop cash crops to improve living standards and raise income.
-

Source: Ministry of Agriculture, Zhongguo Han qu Nongye de xi wang (Prospects of Dryland Farming in China), Beijing, Foreign Language Press, June 1999.

In 1998 the central government invested 1 billion RMB in this project. The State Planning and Development Commission has overall responsibility for comprehensive planning for this program. In 1999 the central government added another 500 million RMB in investment funds for this program. Half of this sum was allocated to MOWR, Department of Rural Water, for irrigation and the development of water saving technology and half was given to MOA to develop dryland-farming technologies.

Mr. Xie noted that MOWR is responsible for making progress on the "water saving program" i.e., he engineering component of the program. He said MOWR will be allocated 1 billion RMB per year to implement this program. With regard to the pricing of water he said the State Planning and Development Commission has the lead but MOA is involved. MOWR is responsible for both surface and ground water.

MOA has 250 million RMB to cover 4 main parts of its dryland-farming program. First, some funds will be allocated to develop improved drought resistant varieties (They are counting on bio-tech to help maintain high yields). Second, some funds will be devoted to long run sustainability (conservation). Third, they want to improve their use of organic manure and fourth they want to improve their ability to monitor soil conditions and soil moisture conditions. To put this investment sum in perspective the Team found an article in China Daily, September 13, 1999 which reported that the government has budgeted 15.26 billion RMB (US$1.8 billion) for water conservation projects for 1999. Of this amount 90 percent will be earmarked for flood control projects and in particular to improve the dykes along major rivers to prevent flooding. Clearly, the investment decisions show that very high priority has been given to flood control and only a small amount for the dryland-farming program.

Mr. Xie stated that the dryland farming and water saving programs are part of the Agricultural Action Plan for China Agenda 21. Investments will be made in the future but the actual amounts have not been decided yet. The World Bank and the Asian Development Bank are interested in these programs.

The Team asked Mr. Xie which river basin MOA was most concerned about and he said the Yangzi basin. The south has good water resources and temperature conditions for agricultural production. The northern part of the country has water constraints hence we have to be realistic about future prospects—in the north we need to get better at growing crops in dryland conditions.

Possible Cooperation Topics

In response to a question from the Team with regard to what kinds cooperative projects in which MOA would be interested, he responded by saying they are interested in water saving cultivation practices, mechanization, using bio-tech techniques to produce drought resistant plants (plants which use less water), and sustainable farming techniques.

Crop Management Department (Zhongzhiye Guanli Si)

Mr. Zhu Yu reported that the prime functions of his department are as follows: conduct research projects to improve field crops; direct crop production (provide policy guidance); provide guidance for farmland construction; give direction on the use of chemical and organic fertilizers; provide direction to farmers when they encounter drought and flooded conditions (including the allocation of relief supplies of seed and fertilizers); provide research to help farmers store grains on-farm; set up procedures for the export of seed and germ plasm; supervise the inspection of domestic quality of chemical fertilizers and pesticides; provide regulations on plant quarantine, and conduct research on soil, water, and plastic film.

Mr. Zhu reported that according to his information about 97 percent of China's irrigated lands are watered through surface flood operations and that the remaining 3 percent are accomplished through spray, drip and micro irrigation. According to the 1998 agricultural census about 15.3 million hectares of land of a total of 53.3 million is subject to water saving practices. Anti-seepage canal systems deliver water to 8.67 million hectares. Pipes and low-pressure system deliver water to 5.2 million hectares. Spray systems deliver water to 1.2 million hectares. There are some spray systems in many parts of China, which mostly deliver water to economic crops. In particular a large part of spray systems are located in the Beijing area. Micro irrigation systems deliver water to 266,670 hectares.

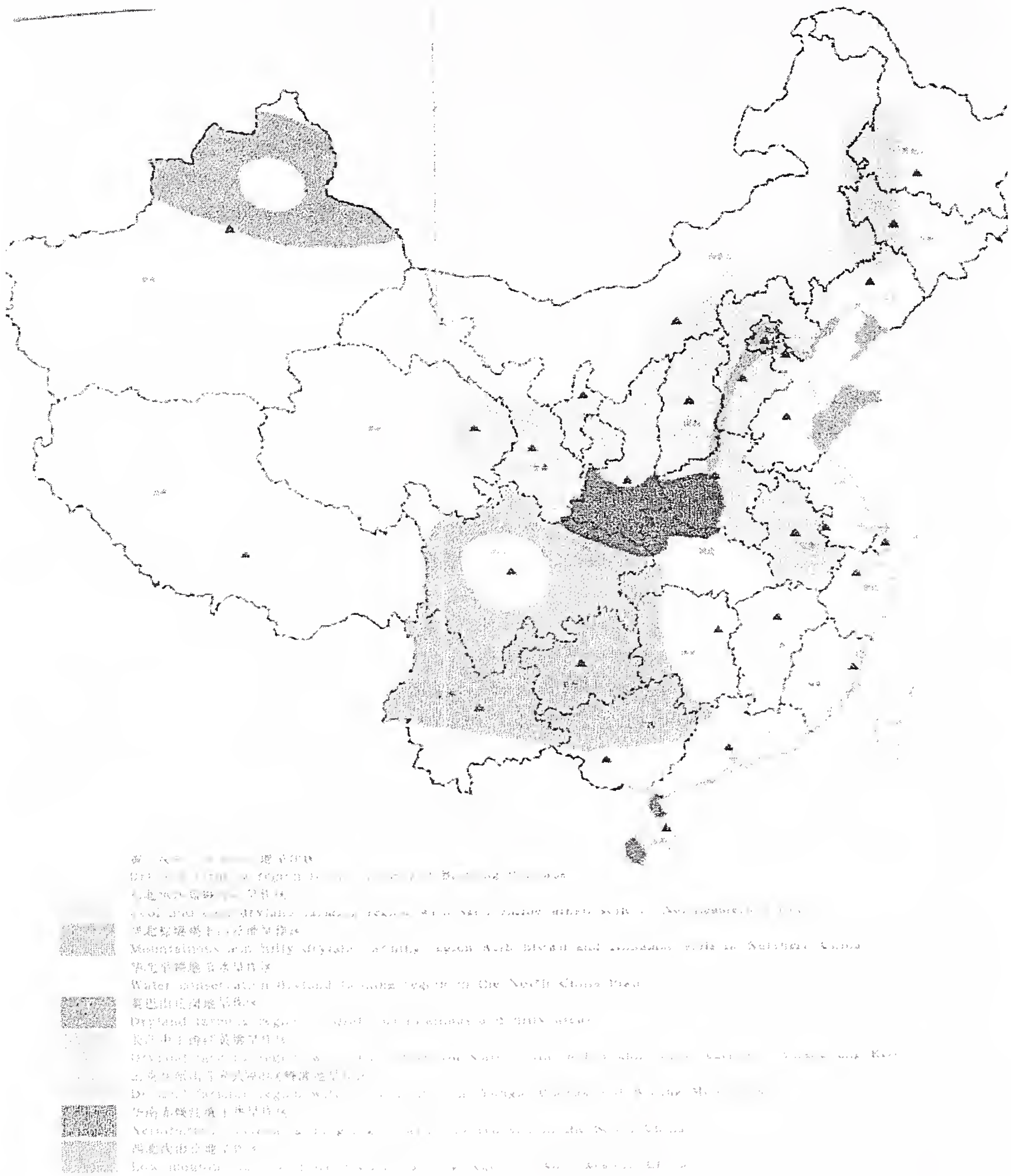
The "dryland farming" program is scheduled to be implemented in 27 provinces in the country. Even provinces in south China where water resources are abundant have some areas which have relative water scarcity and must pay attention to dryland farming. He said that 46 percent of food grains are currently raised as dryland crops, 61 percent of China's cotton crop is dryland, 72 percent of the soybeans and 46 percent of oilseeds (peanuts, rapeseed, and sunflowerseed) are raised as dryland crops. See Figure 2-2--MOA's sketch of Distribution of Dryland Farming Areas in China

Mr. Zhu said there is potential to expand crop production if they can find ways to improve crop yields in dryland areas. He acknowledged that the use of irrigation water has a dramatic effect on grain crop yields, i.e., wheat. But he said the use of plastic film can also increase crop yields.

With regard to the scale of farms in China Mr. Zhu said the irrigated farms in east and south China tend to be rather small and the dryland farms in north and west China tend to be larger. He said that the scale of farms has an effect on the kinds of irrigation systems, which can be employed in China. Center pivot systems can be used on state farms and in some suburban areas. On the whole systems need to accommodate single or small groups of farm households.

He reported that his department is active in extending new technology and information to farmers through classes, TV and radio programs. Also specialty associations have been formed for example local apple growers associations.

Figure 2-2--MOA's sketch of Distribution of Dryland Farming Areas in China



With regard to the problems of agriculture contaminating surface and ground water, Mr. Zhu said they do not have a lot of data on that issue right now. In some areas like Taihu Lake there is a problem with nitrogen in the water because of the high use of chemical fertilizers. In the past the objective was to maximize grain output and farmers applied large quantities of chemical fertilizers. Now there is less emphasis on that objective and environmental considerations are coming to the fore—we should use less nitrogen.

Mr. Zhu reported that the MOWR has responsibility for water issues in rural areas. MOWR has a water station located in each township and MOA has parallel officers (crop production specialists, livestock extension etc). MOA officers in the township level advise farmers on how to effectively use the water available to them. Mr. Zhu said that MOWR has responsibility to promote and push the water saving program (engineering projects, reservoirs, canal systems) and MOA has responsibility for promoting the "dryland farming program."

The Team asked about how farmers are involved in these programs. Mr. Zhu said that in the greatly water stressed northwest farmers are enthusiastic about water saving. But in other parts of the country, farmers are not that interested in water saving. The government has a great interest in saving water but farmers are not. The cost or price for water is low and farmers want to keep it that way.

The book Prospects of Dryland Farming in China, given to the Team included the following measures:

Big and deep furrows on the contour (Northern Shanxi province)
Construction of small scale water catchment systems with cisterns (Gansu province)
Deep plowing, harrowing, and packing seed beds
Composting wheat straw
Use of animal and poultry organic fertilizer
Use of plastic film
Use of corn stalks as mulch
Use of wheat straw as mulch
Low tillage sowing of corn in wheat stubble
Use of pebbles as a field cover
Breeding drought resistant varieties
Intercropping and interplanting
Low pressure pipe irrigation system
Drip irrigation systems
Various types of sprinkler irrigation systems
Water newly planted seeds by hand
Use of tractors to put water, seed, and plastic film down on seedbed at the same time
Developing new types of seeders, attachments to put down plastic film

Source: Ministry of Agriculture, Zhongguo Han qu Nongye de xi wang (Prospects of Dryland Farming in China), Beijing, Foreign Language Press, June 1999, 70 pages.

Agricultural Mechanization Bureau

Mr. Pan Xue-feng reported that his bureau has four divisions: Science and Technology; General; Industrial Development; and a Management Division. One of the prime functions of the bureau is to provide policy guidelines on agricultural mechanization. In earlier years they were involved in design and production but now tractors and agricultural machinery are produced by enterprises and not by line government units.

Dr. Pan gave some data on degrees of mechanization for various crops.

Crop	Percent machine planted	Percent machine harvested
Wheat	67 %	60 %
Rice	4 %	10 %
Corn	36 %	2 %

Source: State Statistical Bureau. Zhongguo Huanjing Tongji, 1998 (China's Environmental Statistics, 1998), Beijing, Tongji Chubanshe, August 1999, p. 112.

Dr. Pan noted that most agricultural machines are privately owned and that only small numbers of machines are owned by collectives.

Dr. Pan reported that his bureau is developing several machines, which will improve irrigation. His bureau has developed a small tractor which plants two rows of corn, put down water at the rate of 3 to 4 cubic meters per mu, and covers the rows with a thin layer of plastic film to raise soil temperatures and to conserve water. They have demonstrated this machine in provinces in Hebei, Liaoning, IMAR, Gansu and Ningxia. The bureau also has developed a spray rig, which works off a 15 horse power tractor, and uses a reel to roll up the plastic pipe as the spray rig moves down the field. The source of water in these cases came from cisterns.

Their plan for the next 10 years is to develop small-scale low cost machines for farmers. They want to design moveable water saving irrigation machinery (xing zou shi jie shui guan gai ji shu).

With regard to measuring irrigation efficiency Dr. Pan said that the Irrigation Center in the MOWR may work on irrigation efficiency. In his bureau his experts only examine efficiency of irrigation machines in experimental plots.

Chinese Academy of Agricultural Science (CAAS)

On Thursday, September 16, 1999, the Team visited CAAS. CAAS was established in 1957 and currently has a staff of over 10,000 and is composed of some 38 institutes. Dr. Mei Xu-rong organized CAAS members to brief the USDA Water Team.

Institute of Agricultural Economics

The Institute was established in 1958 as one of the many institutes in CAAS. Currently the institute has a staff of 100 and is organized into 5 research divisions and one editorial office (Problems of Agricultural Economy and the Journal of Agro-Technical Economics {quantitative}. The 5 divisions are: Resource Economics and Poverty Study Division; Animal Husbandry Economics Division; Agro-Technical Economics Division; The Center for International Agricultural Trade (Cheng Guo-qiang) and Center for Chinese Agricultural Policy (Huang Ji-kun).

Center for Chinese Agricultural Policy

The Center was formed in 1995 with Huang Ji-kun as the director. The Center has a four fold missions defined as follows: a) to understand the problems and uncertainties facing both the makers of China's agricultural policy and the producers of its food, as well as to identify the constraints that are keeping these groups from meeting their goals on increasing agriculture's share of China's growing wealth; b) to develop alternative policies that can assist China in meeting its food economy's goal on a sustainable basis in such a way that China can meet its basic food and fiber needs while maintaining its natural resource base; c) to evaluate the goals of agricultural policies and the results of their implementation as China continues to develop and transform itself from a planned society into a modern, market oriented economy; and d) to make the results of its research available to both government and private domestic and international organizations are in a position to apply them or use them to stimulate China's food economy development and the role of China in the world food economy (From the Centers brochure).

The Center has 5 groups which focus on specific topics: 1) Production, resource and environment; 2) Consumption and nutrition; 3) Price and marketing; 4) Food demand, supply, trade and outlook; 5) and Household food security.

Main Functions of CAAS in Water Issues

Dr. Mei reported that CAAS currently has some 18 programs, which focus on China's water use, irrigation, and drainage issues (see Chapter 5 for details).

CAAS's Water Use Efficiency Studies

Institutes within CAAS have cooperated with outside ministries and units to conduct "water use efficiency" (WUE) studies. The studies have been conducted on regional, county and experiment stations. During the 7^{th} (1986-1990) and 9^{th} (1996-2000) Five Year Plans CASS participated in WUE in areas in north and northwest China. Research on WUE has been conducted for major crops in many areas throughout the nation. The results have been published in the Atlas of Crop Water Requirements of China and Water

Requirements for Main Crop Plants and Their Irrigation in China. Mr. Feng, MOWR, gave the Team a copy of the latter book which was published in 1993, 376 pages.

CAAS Research on Using Sewage water for Irrigation

Mr. Li Jiu-sheng, CAAS, Agrometeorology Institute, reported that the Agro-Environment Protection Institute in Tianjin has concluded research programs on this topic. Research projects included processing of raw sewage for irrigation purposes, irrigation schedules, and in 1995 produced a "National Standard for Irrigation Water Quality."

The use of sewer water in irrigation has expanded rapidly from watering 1.4 million hectares in 1982 to 3.1 million in 1991. Currently the annual amount of sewage is between 35 and 40 billion cubic meters.

CAAS Views on China's Water Supply

Mr. Li Jiu-sheng said that for 1993 China's water supply was as follows.

Surface water source	421.1 billion cubic meters	80.7 %
Aquifers	86.4 "	16.5 %
Sewage	4.9 "	0.9 %

The water supply for China increased by 79.2 billion cubic meters from 1980 to 1993 of which 28.8 billion came from the north and 50.4 billion came from the south. In the north in this period the supply from surface water stayed about the same but water from aquifers increased substantially. Most of the increase in water supply in the south came from surface water.

The exploitation of aquifers in north China is about 74 billion cubic meters, which accounts for 86 percent of the total ground water exploitation in the whole of China.

There are 3.3 million irrigation wells in north China, which irrigate 13.3 million hectares accounting for one-fourth of the total irrigation acreage (54.7 million hectares).

CAAS View on Aquifers

They classified groundwater resource aquifers in three types.

1. "Hole" aquifer (kung-xi), which accounts for 33 percent of total national area. This aquifer is located mainly in the lower reaches of river plains.
2. "Rock" aquifer (yan-rong {karst}), which accounts for 13 percent of national total area. This aquifer is located mainly in the Pearl (Zhu) river region, the Yugui tableland, and in the Taihang mountain region.
3. "Cranny" aquifer (lie-xi), which is located mainly in mountainous areas.

Ground water distribution was given as follows.

District	Billion cubic meters of groundwater
Heilong river	43.1
Liao	19.4
Hailuan river basin	26.5
Yellow river basin	40.6
Huai river basin	39.3
Yangzi river basin	246.4
Pearl river basin	111.5
Zhe min tai	61.3
Southwest all river basins	154.4
All inland rivers	82.0
Er qi si river	4.3
Total	828.8

CAAS on Ground Water Use in the Hai Basin

Mr. Li Jiu-sheng reported that 58 percent of the total water supply for the Hai basin comes from ground water. In Beijing the percent of ground water to total supply was 63 percent, 71 percent for Hebei and 61 percent for Shanxi.

Mr. Li reported that at present the exploitation of aquifers in Hai, Yellow, Huai, and Song-Liao river basins have exceeded or approached the limitation. The annual exploitation of aquifers has reached 105 to 143 percent of the mean available amount For the Hai basin this demonstrates that the aquifers on the plain in north China are being excessively exploited.

Ms. Wang Jin-xia summarized the situation in the Hai basin: urban and industrial demand for water in the basin increased leaving less water for agricultural use. Reservoirs in the basin used to supply water for agricultural use but now they are only supplying water for urban and industrial use. Ms. Wang said that 60 percent of the irrigation water used in the north China plain comes from ground water and 40 percent from surface water. Farmers are drawing out 24 billion cubic meters of ground water each year. By her account they are overdrawing the aquifer by 4 billion cubic meters each year.

Ground water levels in the Beijing area from 2-3 meters below ground level. In some places the level is down 70 to 90 meters. Ms. Wang said that Huang Ji-kun forecasts that the aquifer will be depleted by 2010.

Ms. Wang reported on some research projects underway at the Institute of Agricultural Economics. They have a plan to study local water institutions and the management of water. They plan to identify determinants, which affect water efficiency. They want to look into the cost of irrigation, property rights and incentives. They want to evaluate the

cost effectiveness of different water saving efforts: ditch lining, sprinklers, drip, and better irrigation scheduling.

The USDA Team asked CAAS researchers what they thought would happen when groundwater in the Hai basin become increasingly expensive or depleted. There was not a clear response, except that grain yields likely would decrease by some 30 percent. In past history on a temporary basis regions shifted from irrigated to non-irrigated situations because of the lack of surface water.

Conjunctive Use Approach Being Used

In China many wells have been dug in some large gravity flow irrigation districts to realize the benefits of combining well water with surface water. CAAS researchers pointed out that Yellow River water has been diverted in Henan and Shanxi and they have made simultaneous use of both surface and ground water. The Jinhui irrigation district in Shaanxi also uses a combination of well and surface water.

It is not clear to me that they are thinking about the whole flow…rather a district is short of surface water and so they drill wells?

Farmland Irrigation Research Institute

The MOWR and CAAS founded the institute in 1959. The institute has a staff of 178 and is located in Xin xiang prefecture, Henan province. The institute has 9 divisions (see Chapter 5 for details).

Mr. Qi Xue-bing reported that the institute is working on an number of research projects: water management, optimal allocation of irrigation water, and forecasting irrigation water requirements. They are also working on the use of waste water for irrigation purposes (Shangqiu district in Henan province). In Li min, Yi cheng county in Shanxi province they are working on irrigation costs. Along the Victory Canal in Henan and the Jing Hui canal, Shaanxi Province, they are studying the joint use of surface and underground water.

Mr. Qi said his institute has made a distribution map which gives the water requirements for wheat, rice, corn, and soybeans.

Mr. Qi said his institute has developed an information network on ground water (xin-xi-wang). It is not a computer based network system with chat room and data bases. Every other year they have a national conference on ground water. Data from this network has been used by central leaders in designing irrigation facilities. They gave us copies of China Underground Water Information Network and the Underground Water Study Group, Agricultural Water Conservancy Committee, China Water Conservancy Society, Editors, Di-xia-shui Kai-fa Li-yong Yan-jiu yu Shi-xian (The Opening Up, Study, and Practicality of Using Underground Water), Beijing, Zhongguo nongye keji Chubanshe, August 1999, 246 pages.

CAAS Studies of Water Requirements for Major Crops

Mr. Yan Chong-rong reported that many CAAS researchers have been working on water requirements for major crops such as wheat, rice, corn, potatoes, and soybeans. Mr. Yan gave us copies of a paper he prepared and the pertinent tables have been reproduced (See table 2-2 to 2-13). Mention should also be made the MOWR gave the Team several volumes of crop water requirement published in 1987. Chen Yu-min, Guo Guang-shuang....Editors, Zhongguo Zhuyao Zuowu Xu-shui-liang yu Guan-gai (Main Crop Water Reqirement and Irrigation of China), Beijing, Shui li Dian li Chubanshe, April 1987, 376 pages.

Table 2-2—Early rice and late rice water requirements in South China.

	Growth period days		Average water requirments in (mm)	
Region	Early rice	Late rice	Early rice	Late rice
Guangdong	86-95	92-101	460	509
Hainan	104	90	467.8	466.2
Guangxi	89	93-102	347	335.7
Fujian	83-92	99-109	393.5	514.8
Huei	80-92	92-97	377.3	380.7
Anhui	78-81	79-94	368	431
Hunan	70-78	83-85	352.5	459
Zhejiang	70	na	309.8	na
Sichuan	80	93-100	301.4	416.9
Jiangsu	67	83	343.7	375

Table 2-3—General rice water requirements in South China

Site	Growth periods days	Water requirements in mm
Guangxi	97-118	597.6
Hubei	105-117	556.4
Anhui	89-110	501.8
Guizhou	86-93	414.4
Sichuan	93-100	383.3
Jiangsu	101	519.5

Table 2-4—Rice water requirements in North China

Site	Water requirements in mm
Shenyang	582
Yingkou	717
Dandong	505
Dallian	632.2
Jingzhou	735
Hebei	685.4
Jilin, Lishu	589.4
Jilin, Xingxingshao	461.5
Jilin, Hailong	533.3
Jilin, Qiangguo	549.8
Jilin, Shunan	451

Table 2-5—Wheat water requirements.

Site	Winter wheat water requirements	Spring wheat water requirements
Hebei	452.8	NA
Shanxi	430.8	NA
Shandong	477.5	NA
Shaanxi	476.9	NA
Qinghai	NA	452.5
Guanshu	NA	858.8
IMAR	NA	593.2

WR Crop water requirement in mm
WRI Intensity of crop water requirement in mm per day
AR Allocation ratio of crop water requirement in percent

Table 2-6—General information about the sites.

Site	Province	Latitude	Longitude	Altitude (m)	Annual Precip Itation (m)	Annual temp erature (mm)
Mengjin	Henan	34*50'N	112*26'E	321.2	657.2	13.7
Luoyang	Henan	34*40'N	112*25'E	154.5	615.5	14.7
Tunliu	Shanxi	36*19'N	112*53'E	952.3	551.3	9.4
Shouyang	Shanxi	I37*54'N	113*10'E	1060.4	511.3	7.4
Wuchuan	IMAR	41*06'N	111*27'E	1595	355.1	2.5
Changchun	Jilin	43*54'N	125*13'E	236.8	571.6	4.9
Shijiazhuang	Hebei	38*04'N	114*26'E	81.8	581.7	12.9
Heze	Shandong	35*15'N	115*26'E	49.7	680.8	13.6
Wugong	Shaanxi	34*18'N	108*04'E	505.4	646.8	12.9

Table 2-7—Winter wheat water requirements (Mengjin).

Growing stage	Days	Water requirement (mm)	Intensity of crop water requirement (mm/days)	Allocation ratio of crop water requirement (Percent)
Seeding-overwintering	61	78.1	1.28	15.9
Overwintering-recovery	71	55.8	0.72	11.4
Recovering-jointing	38	59.9	1.58	12.2
Jointing-heading	36	139	3.86	28.3
Heading-jointing	36	158.1	4.39	32.2
Total growing period	248	490.9	1.98	100

Table 2-8—Spring wheat water requirements (Wuchuan).

Development stage	DAYS (d)	WR	WRI	AR
Seeding-jointing	66	166.5	2.52	44
Jointing-heading	25	109.7	4.39	29
Heading-filling	21	73.8	3.52	19.5
Filling-ripening	14	28.2	2.01	7.5

Total growing period	126	378.2	3	100

Table 2-9—Water requirement for spring and summer corn.

	Spring corn (Tunliu)				Summer corn(Mengjin)			
Development stage	Days (d)	WR	WRI	AR	DAYS(d)	WR	WRI	AR
Seeding-jointing	41	68.7	1.68	15.9	20	66.5	3.33	18.5
Jointing-heading	50	158.4	3.17	36.7	31	123.1	3.97	34.3
Heading-filling	22	72.6	3.3	16.9	20	73.8	3.69	20.5
Filling-ripening	54	131.6	2.44	30.5	31	96.1	3.1	26.7
Whole growing period	167	431.3	2.58	100	102	359.5	3.52	100

Table 2-10—Water requirements for cotton.

	Wugong			Shijiazhuang		
Development stage	WR	DC	WRI	WR	DC	WRI
Sprouting stage	105	13.2-20.0	1.8	96	14.8	2.57
Bud appearance stage	90-105	13.2-17.1	3.3	143.6	22.1	6.66
Flower-boll stage	270-450	51.4-56.6	6.3	329.7	50.7	7.62
Boll-wad appearing stage	60-135	11.4-16.9	1.1-3.3	80.5	12.4	2.13
Total growing period	na	525-795	na	649.8	100	4.65

Table 2-11—Water requirements for millet.

	Spring millet (Shouyang)				Summer millet (Luoyang)			
Development stage	DAY (d)	WR	WRI	AR	DAY(d)	WR	WRI	AR
Seeding-jointing	50	132.9	2.66	34	29	57	1.97	16.7
Jointing-heading	31	123.6	3.99	31.6	23	118.3	5.14	34.7
Heading-filling	20	61.9	3.1	15.9	18	83.5	4.64	24.5
Filling-ripening	32	72.3	2.26	18.5	29	82.2	2.83	24.1
Total growing period	133	390.7	2.94	100	99	341	3.44	100

Table 2-12—Water requirements for soybeans.

	Spring Soybean Changchun)				Summer soybean (Heze)			
Development stage	Days (d)	WR	WRI	AR	Days(d)	WR	WRI	AR
Seeding-sprouting	13	20.3	1.6	4	4	19.5	4.9	5
Sprouting-jointing	33	67.2	2	13.4	20	50..7	2.5	13
Jointing-flowering	18	84.4	4.7	16.8	15	66.3	4.4	17
Flowering-filling	43	234.8	5.5	46.7	25	175.5	7	45
Filling-ripening	31	96	3.1	19.1	36	78	2.2	20
Total growing period	138	502.7	3.6	100	100	390	3.9	100

Table 2-13—Water requirements for Sweet potato and Irish potato.

		Sweet potato		Mengjin		POTATO (Wuchuan)		
Growing stage	Days(d)	WR	WRI	AR	Days (d)	WR	WRI	AR
Planting	30	51.9	1.73	9.3	30	79.7	2.66	19.1
Vegetative stage	41	137.8	3.36	24.6	40	162.4	4.06	38.9
Tuber formation	92	347.7	3.78	62.1	41	142.4	3.47	34.1
RIPENING	20	22.8	1.14	4	15	33.2	2.21	7.9
Whole growing period	183	560.2	3.06	100	126	417.7	3.32	100

CAAS Response on Quality of Ground Water

There are three types of pollution problems: 1) sewage water; 2) pollution at water source; and 3) chemical fertilizer and pesticide pollution.

Much of China's sewage is untreated and this has three harmful effects. First, in some cases the soil is contaminated. (Some rice paddies in Beijing were contaminated with industrial pollutants—killed the rice or the rice was not fit for human consumption). Second, the untreated sewage harms the quality of crop produce. Third, the sewage is harmful to citizen's health.

The costs for treating sewage have increased and this fact has made it increasingly difficult for urban areas to treat their sewage. Because of rising costs some sewage treatment plants are not operating at designed capacities.

Ms. Zhang Wei-lu, in CAAS's Fertilizer Institute has done some preliminary work on this topic and CAAS needs to keep up the research effort. Nitrate in ground water has become a problem. Farmers in some areas are applying 150 kilos of chemical fertilizer per hectare of corn.

Center for Water Resources and Conservation Technologies

Was organized in 1996 or 1997 by CAAS to focus attention on water issues. It does not have a permanent staff. The purpose is to coordinate efforts within CAAS and to focus attention on water problems. Their 8-page brochure explains the center's duties and organization. Mr. Xu Yue-xian is the chairman, Dr. Mei Xu-rong, is one of three deputy chairman. Six CAAS institutes are involved in the Center: Research Institute for Farmland Irrigation (Henan); Institute of Agrometerology (Beijing); Science Documentation and Information Center (Beijing); Institute of Crop Breeding and Cultivation (Beijing); Institute of Natural Resource Management; and Beijing Regionalization Agro-environment Protection Institute (Beijing).

They plan to develop drip line irrigation equipment, manufacture the goods and sell the products to users. This seems to be a way for the center to obtain funds to do more research work and to sustain itself.

They also perform consulting services for clients.

Possible Topics for Joint Research

One topic is to focus on the use of water and food security issues. In the past the focus has been on maximizing food grain output. Perhaps the question should be how to maximize farm income from the use of water. Change from looking at crop yields to crop values.

Water quality issues could be addressed—long-term sustainability.

Where should investments be made?

Integrated research on water issues, hydrology, agronomy, economics, sociology, rural and urban development.

Rain water harvesting.

How to move improved irrigation technology from labs to farm use?

We need to study two boundary issues: air to ground; soil water to plants.

We need to work on bio-tech to help develop drought resistant varieties—CAAS can involve 4 institutes on this topic.

Work on monitoring soil moisture conditions, satellite monitoring, ground truth, to improve irrigation efficiency.

Water supply and use tables need to be updated.

We need to take a look at the use of market and price mechanisms to solve water allocation problems.

Water saving technologies need to be linked with economic studies. Why aren't farmers adapting new technology?

We need to study the institutions, which manage water distribution. Since 1980 a fundamental change took place in rural China. Collectives were disbanded and weakened. How has this change affected irrigation systems? How are farmer interests being articulated?

MOWR states that they control the use of underground water and farmers are supposed to get permission to drill new wells, but often farmer just drill wells when they need them. Some farmers are drilling 500 foot deep wells to keep away from using polluted water.

We need help to examine the effects of the falling water table in the north China plain. There has been subsidence and salt water intrusion. We need help on how to manage the aquifer...how to prevent salt water intrusion.

We would like to cooperate on studies, which look at the effect of different water irrigation systems on the environment. How do drip and flood systems affect the environment?

Ministry of Water Resources

Basic Data from 1998 Annual Report

Total water supply available		547 billion cubic meters
Surface water	80.8%	
Underground water	18.8	
Other sources	0.4	
Total water use		543.5 billion cubic meters
Ag use	69.3%	376.6
Industry	20.7	112.6
Domestic use	10.0	54.3
Total water consumption		306.2 billion cubic meters
Ag use	80.5%	
Industry use	9.1	
Domestic use	10.4	
Consumption/use ratios		
Ag	65.5%	
Industry	24.7%	
Urban domestic	26.1%	
Rural domestic	87.7%	
Percent of use	56.3%	
Per capita use		435 cubic meters
Water per 10,000 RMB of GDP		683 cubic meters
Water use per hectare of arable		7,320 cubic meters

Water use in 1998 compared with 1997: agricultural use decreased by 15.4 billion cubic meters; industry use increased by 500 million; and domestic use increased by 1.8 billion cubic meters.

Table 2-14--1998 water supply and use by river basin, in billion cubic meters

Basin	Water supply				Water use			
	Surface	Ground	Other	Total	Ag	Industry	Dom.	Total
Total	441.9	102.9	2.1	547.0	376.6	112.6	54.3	543.5
Song	34.0	28.3	0	62.3	45.1	12.3	4.9	62.4
Haihe	16.1	26.2	0.1	42.4	30.7	6.7	4.9	42.4
Yellow	26.9	12.8	0.2	39.8	30.8	5.8	3.0	39.5
Huai	39.1	17.6	0.2	56.9	40.9	9.5	6.2	56.7
Yangzi	159.4	7.0	1.4	167.9	97.4	49.7	19.2	166.3
Pearl	80.1	4.0	0.1	84.2	54.4	18.8	10.5	83.7
SE	29.8	0.7	0	30.6	20.1	7.2	3.5	30.8
SW	8.0	0.2	0	8.2	6.5	0.8	0.9	8.2
Internal	48.6	6.0	0	54.6	50.7	1.6	1.2	53.6

Source: Ministry of Water Resources. Zhongguo Shui Ziyuan Gongbao, 1998 (Annual Report on China's Water Resources, 1998), September 1999, page 13.

Ministry of Water Resources

Mr. Feng Guang-zhi, gave an excellent overview of MOWR and then discussed the work of his own department which is discussed in detail below in a separate section.

Mr. Feng reported that MOWR is an old ministry, which was restructured in 1998, which resulted in staff reductions and a change in focus. Before 1998 MOWR had both governmental administrative functions and some non-government like activities. In 1998 China's leaders tried to focus ministry functions on giving policy direction, rules, laws, making plans, and allow institutes and enterprises in the socialist market economy to perform their functions.

The primary functions of MOWR are as follows:

- Flood control
- Irrigation
- Manage water resources
- Manage large key construction projects like the 3 gorges dam.

MOWR has ten departments:

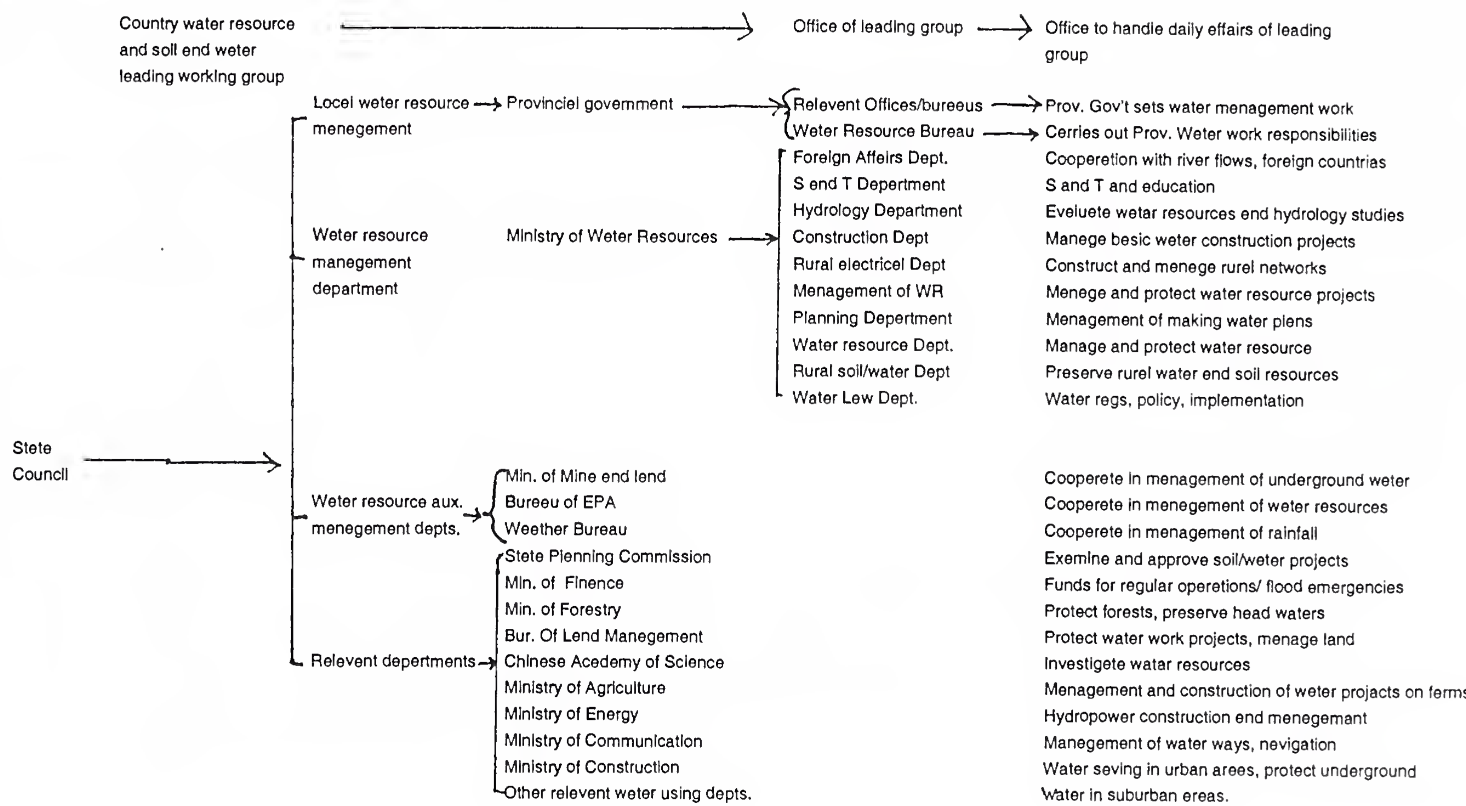
- General Affairs
- Planning and Law
- Policy and Regulations
- Water and Soil Resources
- Economic Adjustment
- Science and Technology
- Water Conservancy
- Rural Water
- Foreign Affairs Department
- Construction

MOWR also manages seven water basins:

- Yangzi River Basin Commission—created in the 1930s
- Yellow River Basin Commission—also created in the 1930s
- Huai River Basin Commission—created in the 1930s
- Pearl River Basin Commission—1980s
- Hai River Basin Commission—1980s
- Songliao River Basin Commission—1980s
- Taihu Lake Commission—1980s.

Mr. Feng noted that the offices for these commissions are located in their respective river basins and do not have titular offices in MOWR Beijing. He said that when MOWR/Beijing officials want to communicate with MOWR river basin commission officials they use the telephone or call them to come to Beijing. At present these commissions have limited power to work on basin wide water problems because provincial governors are very powerful. If there are water disputes within the basin among water users…the commission has limited powers to resolve the conflict. The commission can offer its good offices for the participants to negotiate their differences, but if push comes to shove the issue is brought to Beijing where the State Council has to deal with the issue.

Figure 2-3--Government agencies involved in managing water resources.



Source: 55m Ke Li-xx, June 1998.

Figure 2-4--Water resource management at the local level.

Water resource management at the local level

Level	Gov't	Water management bureau	Mass water management group	Democratic water organs
County	1 Xian shui li ju-- professional	2 Irrigation district or guan gai qu	3 Gan qu guan li wei yuan hui Mass water management group	They vote on policy and level of fees Guan gai qu wei yuan hui 1,2, and 3 leaders attend
Township	Xiang zi guan or xiang shui li ting	Irrigation station, or guan gai zhan	Xiang head of mass organ distribute water and collect fees--or control branch canal, zhi qu guan li wei yuan hui	??? Is there a committee at this level??
Village	Village water cadres	1. Cadres from VC 5 cadres 10-20 people distribute water collect fees 2. VC selects contracting group 3. Villagers form own management group	Shou yi dui-- Village water management asso. Irrigation water delivery team diao di pei shui dui. Distribute water and collect fees	

D:\water/trirpt99/local.ppt

Administrative Hierarchy in the MOWR System

Ministry		Government
MOWR Ten departments Research institutes 7 River Basin Commissions 35,302 employees in the system		State Council
Provincial (Municipality) About 100 employees	Water Office Shui Li Ting	Provincial Governor
Prefecture (City) About 50 to 60 employees	Water Bureau Shui Li Ju	Prefecture Head
County 20 to 30 employees	Water Bureau Shui Li Ju	County Chief
Township 2 to 3 employees	Water Station Shui Li Zhan	Township Chief

Mr. Feng said that provincial governors appoints the head of the Provincial Water Office. MOWR can send down advice, counsel, and directives to their counterparts at lower levels but the officials at lower levels also have to pay attention to the political authorities at their level. These local political officials have the ultimate responsibility to take care of water resource management and the MOWR personnel are primarily technical advisors.

Finance

Budget resources for MOWR comes from the State Council and the budgets for the lower levels comes from their parent political entities, i.e., county governments make funds available to the county water bureau. On some major projects, however, MOWR can send funds down to lower levels.

Before 1980 investment funds for irrigation came from the central government but after 1980 funds for irrigation were to come from local governments. On the whole, Mr. Feng said that MOWR funds are not used to construct irrigation projects. Of the 15 billion RMB budget for 1999, very little will be used for irrigation.

Mr. Feng said that financial data for expenditures and investments in major projects is fairly reliable because MOWR has direct control. But data for rural construction is less reliable. There are two primary reasons. First, local level farmers are mobilized to

contribute labor for projects and valuation of this labor is problematic. Second, local governments invest funds into many small projects and it is difficult to monitor the spending.

Mr. Feng estimated that of total expenditures on the central government's portion are around 16 percent while the remaining 84 percent comes from local governments. He noted, however, that the Three Gorges Dam project funds were not included in these figures. Funds for that dam come directly from the State Council.

Composition of funds expended in 1997 was as follows.

Reservoirs	33 percent
Floods and dykes	16
Irrigation	10
Hydro power	25
Drinking water	10
Other	6

Source of these funds is as follows:

Fiscal	25 percent
Bond ?	20
Foreign sources	10
Construction entities (local government)	33
Domestic loans	14

For more details on financing water resource projects see Chapter 3.

Water Use Fees

Mr. Feng said that when farmers construct a small pond or reservoir for irrigation purposes they form a water management team or office. That person collects water user fees to pay for the maintenance of the pond and the salary of the water master. The collected fees do not usually pay for the cost of the construction of the pond.

The water fees differ by area. In Sichuan farmers pay a water use fee of 9 kilograms of paddy rice for each mou of paddy. In water short Gansu province farmers pay 8 to 10 cents per cubic meter. Urban and industrial users normally pay above cost for the water that they use. The highest price paid for water in China is done so in North China where the fee is 20 cents per cubic meter.

Mr. Feng concluded that as a national average water use fees only covered 50 to 66 percent of the cost of water supplied. MOWR's goal is that user fees pay the water cost (current operating costs) by the year 2000. But this policy is very difficult to implement. The current user fee system does not generate enough revenue to maintain and upgrade facilities.

Department of Rural Water (Nongcun Shuili Si)

Mr. Feng Guang-zhi briefed the Team about the functions of his department. He said that MOWR has responsibility to manage underground water. The Ministry of National Land Resource has the responsibility to survey underground water. Also the Ministry of Construction which is responsible for providing domestic water in urban areas has some responsibilities for underground water in big cities like Beijing and Shanghai.

Feng said that the Hydrology Unit associated with MOWR monitors the condition of underground water. There are several 1000 monitoring stations and years of data have been collected. What data is collected? Mr. Feng said that underground water data is not now published. He referred us to look each year in the "China Annual Water Resource Report" ("Zhongguo Shui Zi Yuan Gong Bao").

Mr. Feng said that in general the levels of underground water has fallen and now it has become a very serious problem. The water level in the Hai basin averages a decrease of from half to a full meter each year.

Of total water used in the country about 16 percent of the supply comes from ground water. Also about 16 percent of total irrigation water comes from ground water (most of this water is used in north China).

Department of Soil and Water Conservation (Shui Tu Bao Chi Si)

Mr. Niu Chong-huan briefed the Team and we note that the major emphasis of his department is soil conservation (and indirectly through soil conservation water conservation)...but in particular his department does not have much to do with water conservation.

The department has three divisions. First, the Planning Division has responsibility for making national soil conservation plans and for handling key national programs. It also handles international exchanges. Second, the Monitoring and Management Division has responsibility for implementing the 1980 national soil and water conservation law. This division handles applications for soil conservation projects. It also handles remote sensing issues. Third, Biological, Environment Construction Division implements national key projects.

Project Implementation

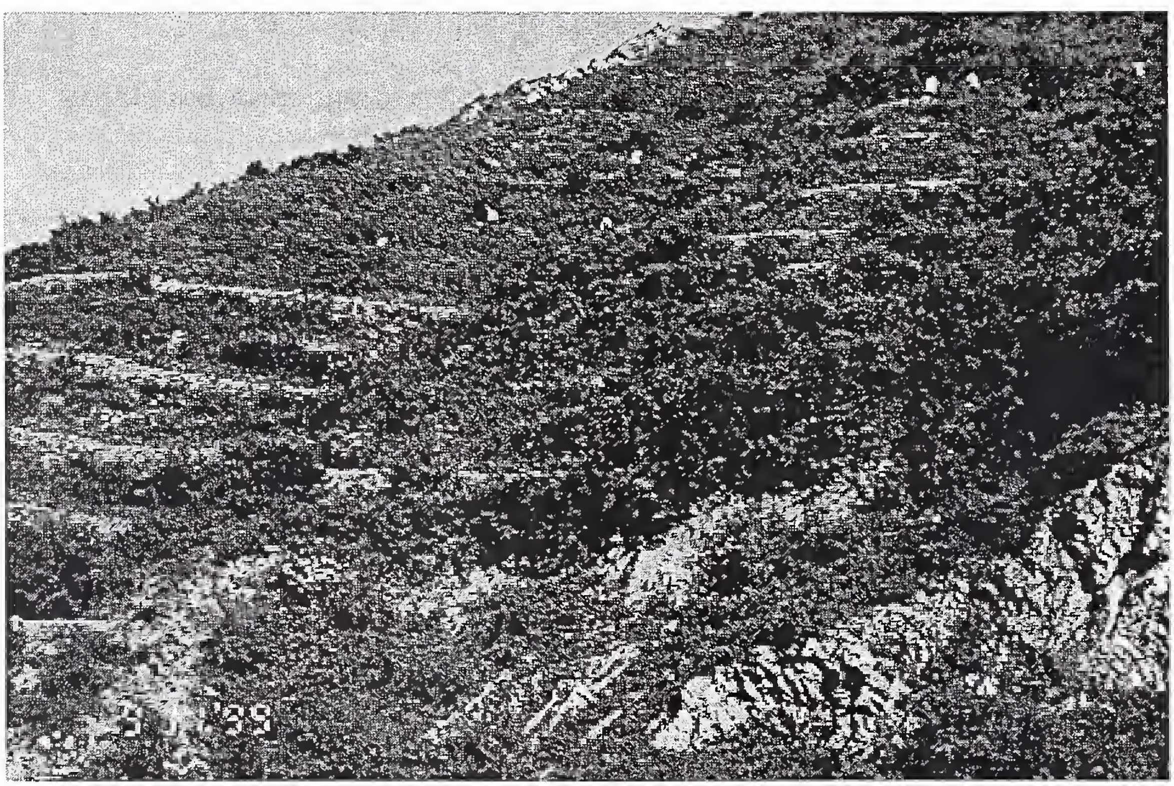
Mr. Niu said that MOWR is in a position to implement soil conservation programs because the central government (Ministry of Finance) allocates funds to the MOWR and it uses these funds to get the job done. Soil conservation plans are made: either MOWR in Beijing formulates a plan (projects) or local water bureaus in province, prefectures,

and county towns submit proposals to MOWR. After the project proposals have been made, evaluated and approved, then the funds are sent down.

For any given project, about 40 percent of the funds come from the central government and 60 percent comes from local government (including the value of labor). Currently, Mr. Niu said that rural residents are required to contribute 15 work days a year to public work projects. Many soil conservation projects are located in low-income areas and the government is considering a proposal to give subsidies to workers in these areas to increase income levels.

For example in building terraces, the government forbids building terraces on slopes greater than 25 percent. He said it takes about 7500 RMB in cash to build one hectare of terrace. The government could provide the bulldozers (tractors) and the trees and grass seed. The township or village could mobilize farmers to do the work. After the project is completed the land could be contracted out to individual households, or if the plot is very large then they may have to re-divide the land. The land use contracts for hillside development may be made for as long as 30 years. Households in the village can negotiate for the contract as well as people outside the village, outside the township, county, province, and he said even foreigners can obtain these contracts. See photo of some men constructing terraces to plant tree (probably fruit trees) in a mountainous area outside of Beijing.

Photograph 2-1--Men constructing terraces on steep hillside.



Team members asked Mr. Niu a number of questions.

Soil Erosion on Irrigated Lands

Does China have problems with soil erosion on irrigated land? Mr. Niu replied that soil erosion was not a serious problem on irrigated lands, although there is some erosion in certain areas where farmers use flood type irrigation.

Salinity Problems

Mr. Niu noted that China does have some salinity problems in the Hai, Huai, and Yellow River basins. His department has some programs to deal with this problem. They dig drain ditches to flush the salts out. He also noted that in the Hai basin they are planting windbreaks to stop wind blown sand problems.

Did MOWR Participate in the 1998 Agricultural Census

Mr. Niu reported MOWR did not participate in the census…it was an MOA affair. He went on to say that MOWR obtains statistical data on water and soil conservation topics through its own system. MOWR prints up reporting forms which it sends to township water stations which fill out the forms and sends the forms up the double track channel (MOWR and government channel) back to MOWR. MOWR recognizes that this reporting system has certain biases and in some cases the data is not too reliable. So MOWR also uses remote sensing techniques and surveys to collect data.

MOWR monitoring stations located throughout the country provide data on stream run off, loads of silt in streambeds, and water quality. Also MOWR experiment stations provide some data to MOWR.

Does the Department of Water and Soil Conservation monitor water quality?

Mr. Niu noted that his department does not monitor water quality. The bureau or institute of Hydrology in MOWR and China's Environmental Protection Agency cooperate to monitor water quality.

Possible Points of Cooperation Between MOWR and USDA

Mr. Niu asked the Team about the use of the RUSLE (Revised Universal Soil Loss Equation) system in the United States. They would like to know more about its use.

Department of Water Resources

On Monday, September 27, 1999, Dr. Frederick Crook and Dr. Diao Xin-shen met with Mr. Chen Ming. He explained that his department has responsibility for policies and is an official government office. The Bureau of Hydrology is not an official line government agency rather it is classed as a shi-ye dan-wei (it is government but not a line

agency rather it is like an institute). It is responsible for managing the hydrology stations around the country and for measuring surface and ground water.

For the discussion on issuing water use permits, see Chapter 3.

Responsibilities

Mr. Chen his department is responsible for planning and management of water resources. They make policies for the distribution of water, set environmental standards, formulate plans, make detailed procedures for the issuance of water use permits. The department has four divisions.

- Planning
- Natural Resource Planning
- Natural Resource Protection
- Water Saving--Chen is the director of this division.

He reported that the Haihe River Water Conservancy Commission is in the midst of making a plan for both surface and under ground water use. The municipality of Beijing is also making a plan about how to match growing demand for water with limited supplies until water can be transferred from south to north by the year 2010.

Under Ground Water

Mr. Chen said that China now has 56 recognized cones of depression which cover some 6,700 square kilometers. By 2000 they will have a map which shows the location of the cones of depression. In these areas his department suggests that no new wells be drilled.

In Beijing land has subsided by 0.8 meters and in Tianjin 2.6 meters. Salt water intrusion is becoming a problem in Hai kou, Hainan province, and along the Bo Hai Bay.

Reasons for Over-drafting the Aquifers

Mr. Chen noted that each area has a specific set of variables. In Beijing over-drafts came from urban and industrial use. In Cangzhou, Hebei Province, over-drafts came from agriculture. In Wuxi, Suzhou, and Changzhou, township and village enterprises drew out the water. In Tianjin and Haikou, industry caused the draw down.

Shallow Aquifers Used Up in the 1960s and 1970s

Mr. Chen explained that during the 1960s and 1970s farmers drilled shallow tube wells and extracted water from this shallow aquifer. As water in the shallow aquifer was used up, wells began to go dry in the 1980s and 1990s.

In search for more water supplies in the 1980s and 1990s users in the Haihe basin went after water in the deep aquifer 200 to 300 meters. We asked if the higher cost of

drilling deep wells and more expensive pumps and electricity are factors in limiting the exploitation of this aquifer. Mr. Chen said, users need the water and they are prepared to pay.

Aquifer Recharge

Mr. Chen said he was not a hydrologist. The experts are studying this problem. When you come next year, we can arrange for you to have a discussion with them on this topic.

He thought as a non-expert that around the city of Beijing the aquifer could be recharged both by natural precipitation and by recharge through canals, i.e., blocking up canals and allowing water to seep into the aquifer.

Problems Stemming from Over Use of Water Resources

Mr. Chen said that in China the water actually used as a percent of water available for use was 19 percent compared with 23 percent in the United States. But in north China the use rate is 40 percent and this high use rate creates problems such as:

- Rivers run dry and do not empty into the sea
- Cones of depression appear
- Land subsidence
- Water quality decreases
- Salt water intrusion
- Desertification

Saving Water: Public Awareness

Mr. Chen gave us a 60 page booklet designed to help the public become aware of China's water problems. The booklet uses text and cartoon figures to illustrate the points. Ministry of Water Resources, Department of Water Resources, Jieshui Zhishi Duben (A Primary Reader on Saving Water), Beijing, 60 pages.

Possible Topics of Cooperation

1. They made a resource survey in the 1970s under the state planning system. Now they want to do a new water resource survey and they would like some assistance on more market oriented evaluations (benefit/cost, efficiency, economic consequences). He said they need a new analytical framework.

2. They would like to learn more about how other countries are handling the water use right issue. How do water markets work? How can water prices be used to help implement the water saving program?

3. We would like to have more discussions on how to manage underground water resources.

China Institute of Water Resources and Hydropower
Water Resource Division

Monitoring of Ground Water

Professor Wang Hao reported that two agencies monitor ground water. First, the Institute of Hydrology, MOWR monitors shallow ground water. Second, Ministry of Natural Resources monitors conditions in deep aquifers.

South to North Water Transfer Schemes

Mr. Wang Hao said that his division, the Division of Water Resources, is working on the south to north water transfer schemes. He said each of the three schemes has a team of researchers analyzing the plans.

East Plan

The east plan will supply water for agriculture, industry and urban use.
one of the problems with this plan is that the water comes through the Huai area and is polluted.

Middle Plan

Mr. Wang believes this plan has the best prospects. Water will have to be pumped up 50 meters so there will be expenses involved with this project.
The quality of the water should be good. The research should be completed in 3 to 5 years. The water will be used for urban and industrial use. The project will deliver 6 billion cubic meters of water annually.

Western Plan

The water will flow into the Yellow River. It will take 30 years to complete this project and will cost 170 billion RMB. The water will benefit agriculture and the environment.

How will conflicts over water issues be resolved?

It is difficult to resolve conflicts over water issues. It is a multi-level, multi-interest, muliti-sector problem.

Professor Wang suggested that a step toward resolving disputes is to first establish some reallocation standards.

1. All have equal water use rights
2. Water resource yield
3. Efficiency
4. Those who invest should get more

Set Standards for Water Shortages

Use some water cycle indexes
- Ecology ground water index
- Natural lake levels
- Natural water flows to the sea

Use some engineering standards
- Calculate water use efficiencies…one cannot claim to be water short if one is wasting water.

Use some economic index standards
- Have there been losses in economic output because of water shortages?
- Have there been losses in levels of employment?
- Changes in marginal price…
  - the local margin should be higher than diverted water.

Consults with the Hai Basin Commission

Professor Wang said that he has attended meetings of the Hai Basin Commission and that he has made suggestions in the meetings.

Water Use Rights

Professor Wang said that the central government has experimented with using water use rights in one place along the Yellow River. Water in China is owned by the state. But user rights can be granted.

He said that local jurisdictions fight for the interests of their districts. The leaders argue that they are representing the will of the people in their district.

Some Progress Made Along Yellow River

Professor Wang said that in the several years the managers of the Yellow River have had some success. They make an annual distribution plan based on water in the dams and under ground water conditions. The annual plan is adjusted monthly to keep up with weather changes.

One problem has been how to punish those who don't follow the rules. Reduce their water allocations in the next year?

Possible Cooperation Topics

Mr. Wang thought that it would be good to exchange books and information on the development of river basins (economic, population, and social aspects).

Water use efficiency needs to be examined. Efficiencies of facilities need to be examined but it is also important to examine effective water use…what economic activities can use water most effectively?

Both sides could take a look at water pricing issues.

Both sides could study the management of aquifers.

Conjunctive use of water could be studied.

China Institute of Water Resources and Hydropower
Irrigation and Drainage Division

Mr., Li Yi-nong, reported that his division has 33 staff divided among three groups: 1) Drainage Group; 2) Salinity Group; and 3) Water Management Group. His division also has a factory, which manufactures soft plastic irrigation pipes. They also produce control valves and do laser leveling.

<u>Three Major Institutes Working on Irrigation</u>

- China Institute of Water Resources and Hydro Power---Daxing County station, Beijing
- Institute of Geography, Yucheng, Shandong
- CAAS, Farmland Irrigation Research Institute, Xin xiang Prefecture, Henan Province.

<u>Factors Affecting Farmer Adoption of Water Saving Technology</u>

Professor Li said one has to work from the conditions of China's farmers. They have small fields, they are tradition bound, and they need equipment, which does not cost a lot of money.

<u>Big Improvements Must Be Made in Flood Irrigation</u>

Professor Li noted that most of China's irrigated land is watered through flood irrigation. Hence if we want to have a short-term impact we must address the issue of raising irrigation efficiency with the flood system.

Farmers are beginning to use a lot of buried plastic pipe to convey water from wells to fields (see chapter 3 for details).

He estimated that buried plastic pipe could be put in for about 1,500 RMB per hectare. He believes about 3.3 million hectares now have the buried plastic pipes and the pipe has been used mostly in Hebei, Shandong, Beijing and Tianjin.

Possible Cooperation Topics

Professor Li thought there could be cooperation on new irrigation technology, land leveling techniques, and surge irrigation systems.

National Environmental Protection Agency

Primarily because of time constraints the Team was not able to obtain an appointment with the National Environmental Protection Agency. But we were able to purchase a pamphlet which listed water targets for the Ninth Five-Year Plan (1996-2000) and long term targets to the year 2010.

The agency assessment is that most of the inland lake and rivers are polluted some worse than others and with time the situation is getting more serious. The agency has developed some water quality standards and has evaluated the bodies of water in the county (see portfolio of maps). Note that the Hai river basin is one of the most polluted in the whole country.

The Agency reports that more than 300 cities are short of water and in more than 100 cities domestic water quality is poor. Source: National Environmental Protection Agency, State Planning Commission, State Economic and Trade Commission, "The National Ninth Five-Year Plan and the Long-Term Targets for the Year 2010 for Environmental Protection, Beijing, China Environmental Press, 1997.

Water Bureau, Beijing Municipality

On Wednesday, September 15, 1999, the Team met Mr. Sun Feng-hua, from Beijing Water Bureau. Mr. Sun said that his bureau employees about 6,000 staff and there are another 6,000 staff in county and township water bureaus and water stations. He said the long term average precipitation in Beijing is around 600 mm per year but the evapotranspiration is around 1200 mm per year, which means that Beijing is basically a water deficit area. Currently the annual supply of water at 4 billion cubic meters just equals the demand for water. One billion cubic meters is used in industry, 0.9 billion for drinking water and home use, 0.1 billion is used for environmental uses, and 2 billion is used for agriculture (50 percent). Beijing has a population of 12 million people so per capita availability of water is very low. About 60 percent of the water supply come from underground water and 40 percent from surface water sources.

Water Distribution Priorities

Mr. Sun said the priorities for water distribution in Beijing was drinking water first, second industry, and third agriculture. He said most of the water used for agriculture comes from underground sources. Water for industry mostly comes from surface water. Drinking water comes from surface sources (Miyun Reservoir).

Solutions for Water Shortages

His bureau has more than a 100 years of weather data and the lowest recorded annual precipitation was 242 mm. This year thus far precipitation has been 250 mm. In other words Mr. Sun said this year has been one of the driest years in the last 100 years.

Mr. Sun said there are several ways to solve the water shortage problem. First, Beijing can increase the supply of water via water transfers from the south. Second, Beijing would like to get water from the Luan River located to the northeast of the city. But this source of water is currently on of the main sources of water for Tianjin Municipality and Tianjin strongly opposes this plan. Third, Beijing can institute water saving programs such as recycling water and improving the efficiency of water use.

Of a total of 346,670 hectares of irrigated area in Beijing, water saving methods have been applied to 253,330 hectares. They are lining canals to reduce seepage. They are using low-pressure pipe systems (Mr. Sun has done a lot of work on this method but it has not been widely adopted. We got the impression that this method is simply using pipes to move water from pumps to the fields). They have installed sprinkler and drip systems.

He defined the efficiency of an irrigation system as the ratio of the quantity of water from the source compared with the quantity delivered to the field (i.e., the loss between the source and the field). He said their sprinkler systems obtain an efficiency of from 85 to 95 percent. The low-pressure systems are at 70 efficiency.

He believes that at present the most important thing to do to save water is to help farmers better manage the application of irrigation water. It is important to help farmers know when to irrigate and how much water to put on the crop. Currently the labor force working in agriculture is composed of older and very young people because families are sending their able and strong workers to labor in higher paying non-agriculture ventures (like township and village enterprises). This means that the quality of farm management has declined. He recognized the need to help farm managers learn how to use water more efficiently.

Relations Between Beijing Water Bureau and MOWR

He said that MOWR and Beijing government are on parallel levels with regard to the State Council. The officers in the Beijing Water Bureau are appointed by Beijing government. The MOWR sends us guidance, which we take very seriously, because MOWR has funds, which we need for our various projects. We do not have to do what they say and we do not have to respond to their requests for statistical information and likewise they do not have to respond to our requests for technical and financial assistance. He said his bureau works very hard to maintain good relations with MOWR.

His bureau can draft proposals, which they can send directly to MOWR—maybe they also send the application to the Beijing government, which may help them, lobby for the acceptance of the proposal.

Also there is the matter of promotions. If one does a good job in Beijing, then there is the possibility of being raised up to work in the Ministry or be promoted to other positions in the government. As an example some officers in his bureau have been promoted to serve as provincial governors.

Underground Water

Mr. Sun said there is a cone of depression beneath the city of Beijing. He gave neither data on the area of the depression nor the depth of the cone at the center.

He said his bureau monitors water pumped out of wells by using water meters. They sample some wells year round to determine water use, depth of water, and water quality.

Possible Cooperation Point

Mr. Sun said that at present China needs help integrating all the important elements at the ground level to improve more efficient use of irrigation water: wind speed, soil moisture, temperature, humidity, to determine when to irrigate and how much water to apply.

Mi Yun Reservoir

On Wednesday, September 15, 1999, the Team met with Mr. Zhang De-ju, Manager of the Mi Yun Reservoir. The reservoir is under the jurisdiction of Beijing Municipality Water Bureau.

Mr. Zhang said the facility was constructed in 1958-1959 during the "Great Leap Forward." The dams are now 40 years old. His office employs 740 persons. The purpose for building the dam was many fold: first, flood control, water supply for industry and drinking water for the city of Beijing and Tianjin, hydro power, recreation (environment), and agricultural water use.

The dam has a designed capacity to hold 4.375 billion cubic meters of water. Seven outlets carry water to downstream users. There is one open canal, which carries drinking water to Beijing and a underground pipe. The water is treated, sediment removed, filtered, and chemicals added before the water is sent into the city water system.

Tong County Water Bureau

On Wednesday, September 15, 1999, the Team met with Mr. Jin Jian-hua, official in Tong County Water Bureau. There are about 6,000 employees in county and township

water bureaus in Beijing. Tong County was selected as one of 300 sites to test water saving technology. We visited the site at Xu Xin Zhuang Town. The fields were regular shapes (455 meters long and 230 meters wide).

Irrigation water for the fields come from both surface and well water. The fields are planted with winter wheat in late September or early October. The wheat is harvested in June and then corn is planted and harvesting takes place in late September.

Plastic pipes were placed in the field at a depth of 30 cm. Every 18 meters they placed a riser from which the sprinklers were attached. Water was applied (34.5 mm) to the field once every 7 days. Normally the annual precipitation is 600 mm with July rainfall at 247 but this year July rain was 48 mm and precipitation since January has been 180 mm.

The ground water level in 1998 was 9.5 meters but in 1999 the level dropped to 14 meters. They use electric motors on the wells, which can move 50 cubic meters of water per hour. They reported that the total dynamic lift in the wells were 78 meters. They said the saturated thickness of the aquifer was 15 meters.

Xu Xin Zhuang Town Water Station

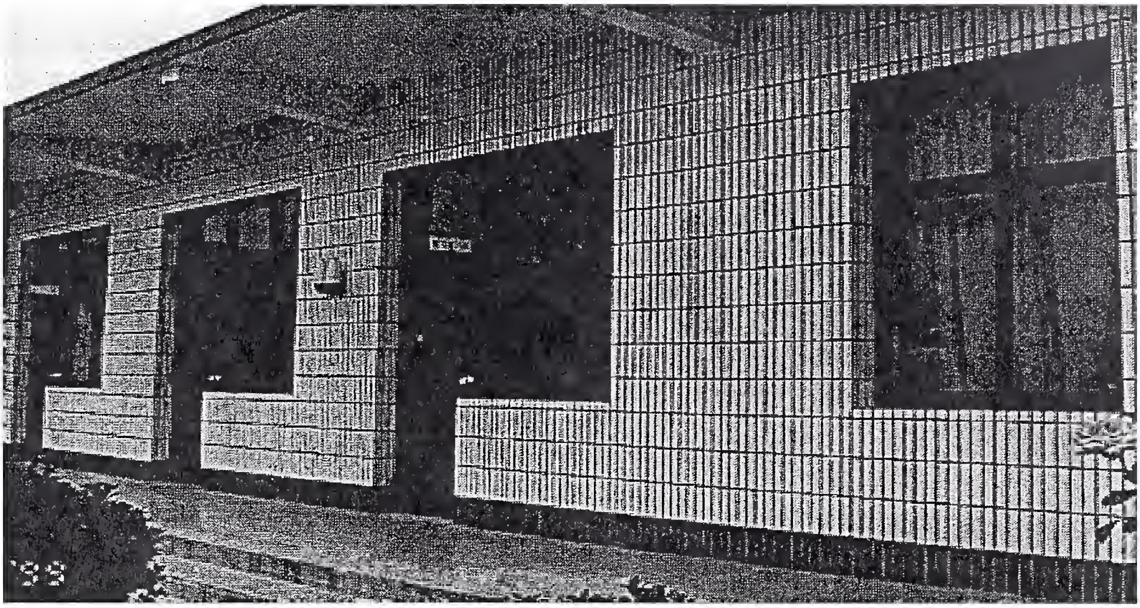
The Xu Xin Zhuang Water Station is part of Tong County Water Bureau. The station has its own set of buildings outside the town. The offices are remarkably modern. Ms. Liang Ai-ying, vice director of the station reported that the station had 10 employees. It is possible that the station's offices are new and nice because the town had been selected to be the site of an experimental site. Probably few township water stations in the whole country are as fancy (see Photograph 2-2--Photograph of Xu Xin Zhuang Township Water Station).

The Team visited a field where 30 vegetable sheds were being constructed. Each shed covers almost one mu of ground or 667 square meters. At the site workers were laying pipes for the drip irrigation system and building a facility to house the filter system. The main lines from the pumps (filter) were 4-inch plastic pipes (22 RMB per meter) put into the ground at about 1-meter. The lateral lines were about ¾ inch plastic pipes (1 RMB) per meter and the drip lines were about 6 mm. The drip lines had a hole about every 30 cm.

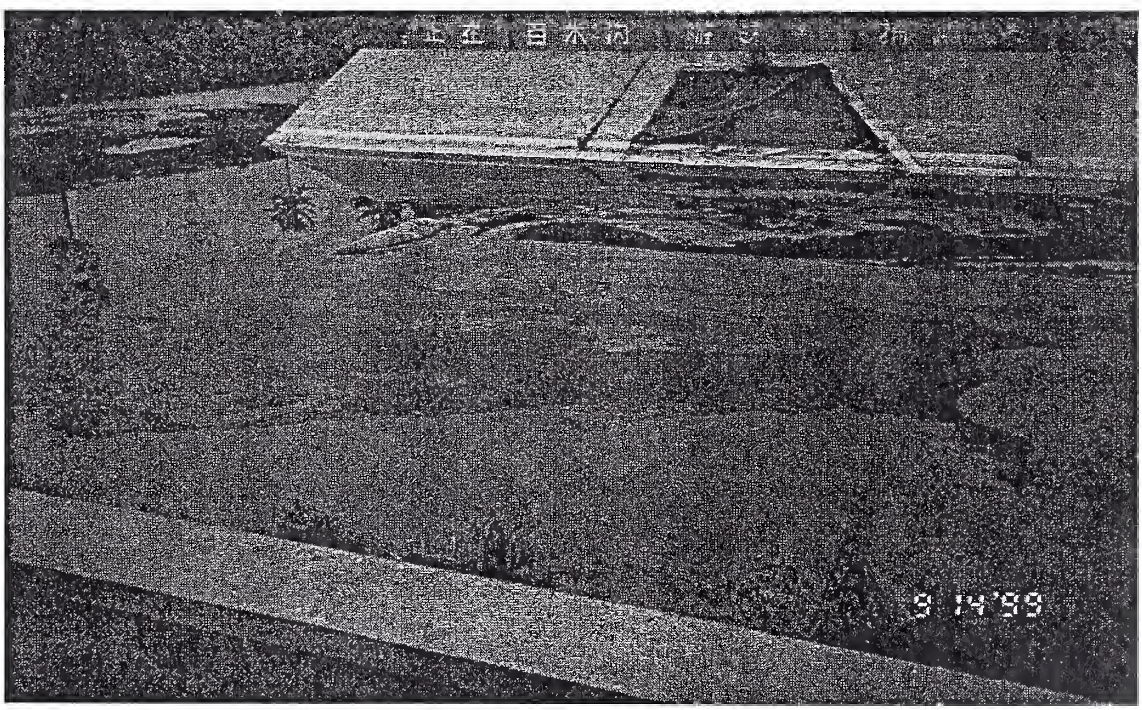
The town water station also housed the equipment, which controlled the irrigation in the experimental fields.

The town has a total of 587 wells; 27 kilometers of underground pipe; 15.5 kilometers of lined irrigation canals; and 17 kilometers of drains. The town has 287 sets of sprinkler irrigation equipment. Ms. Liang reported that 6 million RMB has been invested in water resources in the town. She reported that 91 percent of the grain area in the town was covered by sprinkler irrigation systems.

Photograph 2-2--Photograph of Xu Xin Zhuang Township Water Station



Photograph 2-3--Rubber dam in canal to allow water to recharge aquifer.



Each year they do a survey of the 587 wells and they monitor 40 wells for the whole year. They also monitor underground water situation in 5 wells.

The town drilled 78 new wells in 1999 at a cost of 10,000 RMB per well. Old wells fail for two reasons: first the aquifer dropped, and second sand plugged up the holes in the screens. Normally they get 15 years of service out of a well. The average depth of the wells is 100 meters and the well casings are 30 cm.

They reported that the agricultural use aquifer is down about 100 meters, drinking water aquifer at 150 to 200 meters and city use water at 700 to 800 meters. When asked about recharging the aquifer they reported that 3 rubber dams are used to dam up the Chao bai river (see Photograph 2-3—Water dam on Chaobai river).

Chinese Academy of Sciences, Institute of Geography

On Friday, September 17, 1999, the Team visited the offices of the Institute of Geography where we had some lively discussions and some excellent presentations. One of the Institutes under the Resource and Applied Division is the group studying "Research on Water Resources and Water Environment." The institute also has an "Agroecosystems and Environmental Technology Experiment Station."

Liu Chang-ming on Ground Water Depletion

Professor Liu Chang-ming used a power point presentation to brief the Team with regard to ground water depletion in China, especially in the north China plain. For more details see Chapter 4.

Ground Water exploitation rates have increased from 1986 to 1997.

River basin1	1986	1997
Songliao	30 %	42.5 %
Hai	70	95.7
Lower Yellow	30	31
Huai	15	33.9

We believe he defined the exploitation rate as use / recharge.

Liu Chang-ming on Cones of Depression

Place	Depth of depression in meters	Area of depression in sq. km
Tangshan mining	26.89	202
Tangshan city	48.6	282
Beijing	40	1,000
Baoding	53	283
Shijiazhuang	31	259
Handan	32	
Anyang	15.7	

Professor Liu noted that the environmental impacts of these cones of depression are: 1) they degrade water quality; 2) there is land subsidence (2 meters in Tianjin and 1 meter in Cangzhou; and 3) there is sea water intrusion. He said that here are 61 cones of depression in 20 provinces including 21 deep aquifer cones. The area covered by these cones totals 80,000 square km.

The use of ground water supported rapid economic growth but it has also had an impact on the environment. Liu said some countermeasures can be taken: 1) water saving strategy; 2) artificial recharge; 3) improved management of water resources.

The United Research Center for Water Problems

Professor Li Li-jian, gave a power point presentation on the functions and work of The United Research Center for Water Problems (URCWP). Professor Li said that 32 institutes within CAS and institutes in various cities, i.e., Nanjing Institute of Geography and Limnology to form the membership of URCWP. Professor Liu is the director and Prof. Li is the standing director.

The URCWP has three main activities: consulting for the national and provincial governments; promoting interaction among specialists inside China and abroad; and carrying out research projects.

URCWP has four prime tasks. First, it is supposed to work on China's water cycle and water balances. Second, it studies water resources and global change. Third, it studies regional and river basin water resource exploitation and use. Fourth, it studies water quality issues.

Current research projects include the following.

- Changing water resource use and allocation in north China.
- Efficient water use in agriculture on the north China plain.
- Water use in the Qaidam basin.
- Water resource use and food security issues.
- Evaluation of sustainable development strategies for water use in China.
  - Water resource evaluation
  - Potential use of rainfall (harvesting)
  - Water transfer issues

A project not begun yet is to look at change in water resources and maintaining mechanism of renewable water in the Yellow River basin.

Professor Li gave the Team a number of publications (see publication list) for a full list.

- River hydrology in China
- Hydrological zoning in China
- Water balance in North China and S-N water transfer
- Inter-basin water transfer from S-N
- Agricultural hydrology and water resources in the north China plain
- River hydrology in southwest China
- Hydrology in arid regions of China.

Yucheng Experiment Station

Professor Kang Yao-hui reported that the station is located near Jinan City in Henan province. It is open for use by national and local government researchers and by foreign researchers. The station carries out basic irrigation research and it carries out applied research for provinces who are willing to fund projects.

Professor Xie Xian-qun, and director of the experiment station said that the main projects from 1996 to 2000 (the Ninth Five Year Plan period) are 1) to study how to use scarce water resources and nutrients to increase crop output and 2) to study water and nutrient cycles in each area. There are 30 stations and they will look at these questions from their own perspective, i.e., high rainfall in the southeast and arid conditions in the northwest. This project is to be completed by 2005 (10th Five-Year Plan period). See Chapter 5 for details.

Possible Cooperation Points

There are areas in the United States which have ground water depletion, salt water intrusion, subsidence and one could study and compare reactions to these conditions in the two countries.

Nitrogen in the ground water is a problem both countries face. What counter measures are both countries taking to resolve the problems?

Both countries are studying how to improve water efficiency. But how does each country get its farmers to adopt water saving technology?

Danny Goodwin's map of ground water depletion in Arkansas has been useful to help politicians and farmers understand the coming problems with depletion. Could a similar map be made of the Hai basin to educate residents about possible coming problems?

Tianjin, Bureau of Agriculture and Forestry

On Monday September 20, 1999, Deputy Director Zhang Jie gave a brief overview of agriculture in Tianjin. He acknowledged receiving the Teams list of questions but noted that the Bureau of Water Conservancy would answer most of them. Zhang said that water problems were one of the most serious problems Tianjin faces. Tianjin is a relatively small municipality but nine rivers pass through it.

Arable land	426,000 hectares
Sown area	578,000
Grain area	300,000
Wheat area	151,120
Corn area	152,220
Rice area	66,300

The city has a long term annual average rainfall of 560 but the evaporation rate is 1000 mm to 1200 mm a year. 62 percent of the precipitation falls between June and August. They have weather data going back 90 years: they have wet years 2 percent of the time; normal years 21 percent; and dry years 52 percent of the time.

In 1995 1.2 billion cubic meters of water was used by agriculture of which 800 million came from surface water and 400 million from ground water. Underground water is used for economic crops (i.e., vegetables), and for some double-cropped grain areas, i.e., winter wheat and corn. Spray and drip systems are used in Ji County, which is hilly, and flood type irrigation is used on the plain.

Water from the Luan River (via canals and reservoir system) is used for municipal drinking water and for some industrial use. Agriculture use water has to come from precipitation from within the city or from water flowing through the area.

The Team asked what crop re-allocations would be made is the groundwater table became unusable. Their response was that rice area would fall and there would be an increase in area sown to corn, millet, sorghum, buckwheat, soybeans, and various kinds of beans.

Water Saving and Dryland Farming

Zhang said Tianjin should pursue a water saving and dryland farming policy because of these water shortage conditions.

There is a division of responsibility for this program between the Bureau of Agriculture and the Bureau of Water Resources.

Engineering--Water Saving

Zhang said the Bureau of Water Resources is responsible for flood control, for building ditches (lining ditches), ditches for flood irrigation, pumping stations for irrigation and drainage, spray and micro irrigation.

Agriculture --Water Saving

Zhang said his Bureau is responsible for the cultivation practices, which lead to water savings, for seed development (drought resistant varieties), and for the allocation of sown area to the various crops.

Extension Situation

Zhang said that in most townships the Agricultural Bureau and the Water Resource Bureau staff member cooperate and coordinate their extension work with regard to water saving methods.

Rice

Mr. Zhang Jin-jiang, said that with 9 rivers running through the province Tianjin had to find a way to capture and use some of the water. They dug reservoirs to capture flood run off in the summer and used this water to raise about 53,000 hectares of rice.

They used to waste water in the paddy fields because the fields were not level and they had to add water to cover the entire paddy. Zhang said that they have to flood the paddies to wash away the salt. They have been able to maintain high yields even with water shortages.

Ninghe County is the main rice producing area in the city. It is located northeast of the city center. They depend on surface water to irrigate the paddies. The shallow ground water in that area is salty (it is right next to the Yellow Sea).

Corn

Mr. Zhang Yi-lin briefed the Team on the corn situation in the city. About 80,000 hectares of early season corn is planted in the spring. Another 80,000 hectares is planted after the winter wheat crop is harvested in June.

He said it is important to choose varieties and select the planting times to coincide with the normal heavy rainfall in July and August when the corn plant needs the most water.

He said they use a heavy chisel to break pathways down into the soil--50 cm deep. If they do this they can store about 350 mm of rainfall in the soil.

Wheat

Mr. Yao Zhen-fan said that in a normal year winter wheat fields are irrigated in November after the seeds are planted, once in late March, and once in late April. For those farmers seeking yields of 6 tons per hectare, they irrigate once more in late May. Most of the water for wheat comes from surface water and not from ground water. Some of the double-cropped grain fields do use under ground water resources. Almost all of the wheat crop is irrigated by flood type systems.

Haihe River Water Conservancy Commission

On Monday afternoon, September 20, 1999 the Team met Ms. Ma Xiu-qing from the commission. For details see Chapter 7. She has worked there for many years and said the commission has a staff of about 300 people. She gave the Team 3 brochures, one entitled "Haihe," was 32 pages. For details see Chapter 7.

Tianjin Water Conservancy Bureau

Water Resource Management Office

Ms. Tian Ping-fen, Water Resource Management Office, Tianjin Water Conservancy Bureau had a beautiful map of Tianjin with all the pertinent water information--the map was for domestic use only, i.e., we could not buy one.

Water Resources

Ms. Tian said that Tianjin relied on three sources of water. On the average the city gets about 986 million cubic meters of water from precipitation.

About 1.9 billion cubic meters flows through the city each year. There are some 28,000 wells in the municipality. Irrigation wells constitute 80 percent of the wells. Wells for rural domestic use amount to 11 percent. Wells for industrial use account for the remaining number of wells.

About 700 million cubic meters of ground water is available each year.

Urban Water Use

Water for urban use in Tianjin comes from the Luan river in Hebei province via Pan jia kou reservoir and then by open canal to the city.

Irrigation Water Use

There are three sources for irrigation water: rainfall, underground water and water passing through the city.

Water Use Plans

The MOWR requires us to make an underground water use plan. In 1997 we made some mistakes and encountered some problems. The water conditions are better in the northern part of the municipality than in the southern part. There is little fresh water there and there has been some over drafting in that area.

Underground Water

In 1980 they began to monitor the conditions of wells. In the north the water level was 2 meters but in the south it was 70 to 80 meters. In the north we encourage the use of ground water but in the south we discourage its use. There has been some irreparable damage to the aquifer in the southern part of the city. There we permit no new wells and units have to obtain permission to replace old wells.

Ms. Tian said that there was draw down in the 1970s and 1980s but that now things have stabilized in the 1990s. But the industrial users with their wells in the core area of the city are still drawing down the water table.

They are monitoring 408 wells. They have monitored the conditions of wells every 5 days for the last 10 years. They do the monitoring by hand but now have automatic monitoring devices on about 100 wells.

Water Use Fees

Ms. Tian said that users in urban and industrial areas have to pay 0.5 RMB per cubic meter of water. Irrigation users do not have to pay this fee.

Local Management of Water Resources

Townships and villages organize water management units to distribute water and to collect fees.

Where wells are used some times the wells are contracted to a person who meters out the water to users and collects the fees from the farm family.

Water Diversions

Ms. Tian said that over the past 50 years water has been diverted to Tianjin from other areas. Water from Miyun was diverted to Tianjin but with the increase in demand for water in Beijing this diversion ceased. Second, some water comes from Hebei province via the Yueching via the Grand Canal. Tianjin has the right to a given amount of water from the Yellow river (1 billion cubic meters), but the quantity of water coming down the Yellow river has fallen so Tianjin does not get much help in actual fact. Also water from the Luan River is diverted to Tianjin.

Irrigation Office

Mr. Yang Hui-dong, Water Office, Bureau of Water Conservancy, said that the irrigation conditions in Tianjin were as follows.

386,667 hectares of irrigated land
300,000 hectares of effectively irrigated land *
233,333 hectares were actually irrigated in that given year.

---

*Ms. Tian said there are some criteria for effective irrigated area. In normal years there must be a source of water. Second there must be a channel from the source to the field. And third, there must be some kind of a system to manage the water flow.

He said Tianjin has four major water problems: salinity, flood, water logging and drought and of these four, drought is the most serious.

In the 1960s we had more water than we do now. But in the 1970s and 1980s upstream users used up the water and left us with less water. Tianjin began to dig their own reservoirs to store up water during the heavy rainy seasons in July and August. Then this water was used for irrigation. We have 11 large reservoirs now with a capacity to store 660 million cubic meters of water.

Deep ditches

The deep ditches are used as channels to move water around in the city from surplus to deficit areas. In a way these many canals serve as a kind of storage basins. When fields are water logged water is pumped into the fields, when there is a dry spell water is pumped from these ditches onto the fields.

Water Management

Mr. Yang said there are two large irrigation districts in the municipality: Tuan bo wa and Li zi gu. The Tuan bo wa district was constructed in the 1950 and enlarged in 1994. Investment came from national, city, local, and farmers put in corvee labor.

The Li zi gu system is based around the Chao Bai River.

The Water Saving Program

They take care of the engineering part of the program and have put in facilities to save water on 116,667 hectares. They have lined ditches, put in underground water pipes for 53 percent of the 116,667 hectares and they have put in drip systems on 4,000 hectares.

Open ditches are used in areas, which use surface water irrigation. Underground water pipes are used in areas which use tube wells. Spray and drip systems are used in the mountainous area in Ji County.

He said the investment for these facilities is a cost sharing system where the central government put up say 25 percent, local government a share and farmers contribute their labor for their share.

Topics of Possible Cooperation

Ms. Tian suggested that one cooperative project would be to take a look at how best to use sewage water (wastewater). A great deal of wastewater flows through the city from Beijing. How can we best use this water?

Another project would be to examine how the crop structure could be changed to save water.

A third project might be to examine how to use salty underground water. Can it be cleaned up? Can some crop plants grow in salty water?

A fourth project might be to examine some scenarios assuming different levels of water resources available to Tianjin. How might the economy change if water availability falls? They have already done some work on this topic.

Tianjin, Wuqing County, Water Bureau

The Deputy County head, Zhang You-long introduced Mr. Shi, County Agriculture Bureau and Mr. Chen Bei-hua, county Water Bureau. Mr. Chen said two main waterways traverse the county. Bei yun he (Grand Canal) and the Beijing wastewater canal.

He said the demand for water in the county was 520 million cubic meters but the supply was only 90 million from ground water and 160 million from surface precipitation, which left a deficit of 270 million. Then he said crop requirements were needed for 400 million cubic meters (did not make sense). His main conclusion was that the county was water short and so they took two basic measures. First, they have been tapping into the two canals, which run through the county, i.e. they are using wastewater for irrigation.

Second, they have implemented the water saving irrigation program. They have applied water saving technology to 31 percent of their irrigated area (28,667 hectares / 91,600 hectares of total irrigated area).

Mr. Chen said the county has 43 pumping stations which can be used to pump water out of the canals for irrigation or they can pump water out of water logged fields into the canals. They expect water logged fields in one year our of five.

The county Water Bureau is making a ten-year long term water plan out to the year 2010. First, they want to double the area covered by water saving technology. Second, they want to expand the storage capacity of their reservoirs from 75 million cubic meters to 100 million cubic meters. Mr. Chen said that when upstream runoff flows past the county during the heavy rains in July and August that they divert some of this runoff and store it up for latter use.

He Xi Wu Town

The town has an area of 38.4 square kilometers, 32 natural villages and a population of 25,000 and temporary population of 4,500 (have left the town temporarily). The town is located 60 kilometers midway between Tianjin and Beijing. It used to be a major port along the Grand Canal.

Water Conservancy Station

Since 1991 the town has built some anti-flood facilities and has provided piped drinking water. It has 6 pumps (5,400 cubic meters per hour) at a cost of 3,330,000 RMB. It has drilled 6 wells beginning in 1991 and built 50 water towers and laid 140 kilometers of pipe.

The town has supplied drinking water to 24 villages, 25,000 people, 45 enterprises, 173 family commercial stores, and 3 schools. The domestic water supply is made available 24 hours a day. Do they collect fees?

These two water projects are managed by the town's Water Conservancy Station. The township was selected as a demonstration key point by Tianjin Municipality.

Town Irrigation management District

This district is one of many in Wuqing County. In 1991-1996 they established the Gao Bian Zun Comprehensive Irrigation District with 1,733 hectares, with 370 wells, each supporting 4.67 hectares of land. They put in 133 kilometers of anti-seepage ditches of which 119 kilometers were underground plastic pipe. The cost was 3,751,200 RMB or 2154 RMB per hectare.

In undertaking this project they used unified planning, unified implementation, and unified management. The town has three irrigation management districts, west, middle, and east districts.

They described the aquifers as shallow down to 50 meters, middle from 100 to 150 meters, and deep below 150 meters. They said there were some impervious clay layers down there that separated the aquifers. Between 30 to 50 meters is a layer of sand. They said the water table is falling--6 meters. The salt water in some layers is very old and has not come from the sea. (See chapter 4 for details)

The west district uses surface water because the shallow and middle layers are salty. But the deep wells have fresh water. The deep wells are used to supply drinking water in the town.

The middle and east districts use well water from the shallow and middle layers.

They manage the wells, pumps, ditches, land, and electricity according to a scientific plan (try to save water).

In each village there is a village well management office (cun guan jing chu) or an irrigation team (jiao shui li zu). They distribute the water to users and collect fees (electricity and wage for the manager).

The municipality put up 25 percent of the capital for the well system, the county and town put up 25 percent and the farmers put up 50 percent.

Xin Kou Town

On Tuesday afternoon, September 21, 1999 the Team drove from Wuqing County south and then west of Tianjin to Xin Kou Town. Mr. Yan De-lai, Vice Chief of the Town briefed the Team. The town has 18 villages, 35,000 people, and 2,313 hectares of arable land.

Township Administration

Mr. Yan said he had about 197 total workers in the town government of which 50 were government employees, 70 were shi ye dan wei, 13 were administrative leaders, and 50 section or office leaders.

He said there were about 50 staff members working in the agricultural area: water, mechanization, extension (7 people), livestock, forestry, and rural economic management.

In administration he had an office of family planning, finance, education, transportation, internal affairs, and 3 persons in the statistical group.

Farmers

Mr. Yan said that individual farmers own their own small pumps and plastic pipes to irrigate their vegetable plots and orchards. Farmers were using their own small tractors to supply power for these pumps, which were drawing water out of a large canal. See Photograph 2-4--Farm family pumping water with their own power source.

Mr. Yan said that farmers use the land under a land contract system and they have to pay rent for use of the land (cheng bao fei). Rather than collecting water use fees from the farmers for the actual water they use, Mr. Yan said that the electricity fee is made a part of the rent number. We also think that profits from the industries in the town are used to offset the irrigation costs.

Under Ground Water

The town is implementing the water saving program. They are exploiting shallow ground water 30 to 60 meters. They said this aquifer can be recharged from precipitation, which mainly falls in July, August and September. They have 350 wells with each well serving about 2 hectares. Mr. Yan said that they hired outside companies to come in to drill the wells down to 30 to 50 meters. The cost was about 5,000 RMB per well including the pump. He said the wells were spaced out along electric power lines. See chapter 5 for details.

Water Storage

Because of water shortages they try to store water. They use the canals and ditches in the town to store water. They have 100 kilometers of canals with a width froom 13 to 26 meters and they figure they can store 1.5 million cubic feet of water this way from the precipitation, which falls in July and August. They also can obtain water from the flood control canals, which pass through the town (6 million cubic meters).

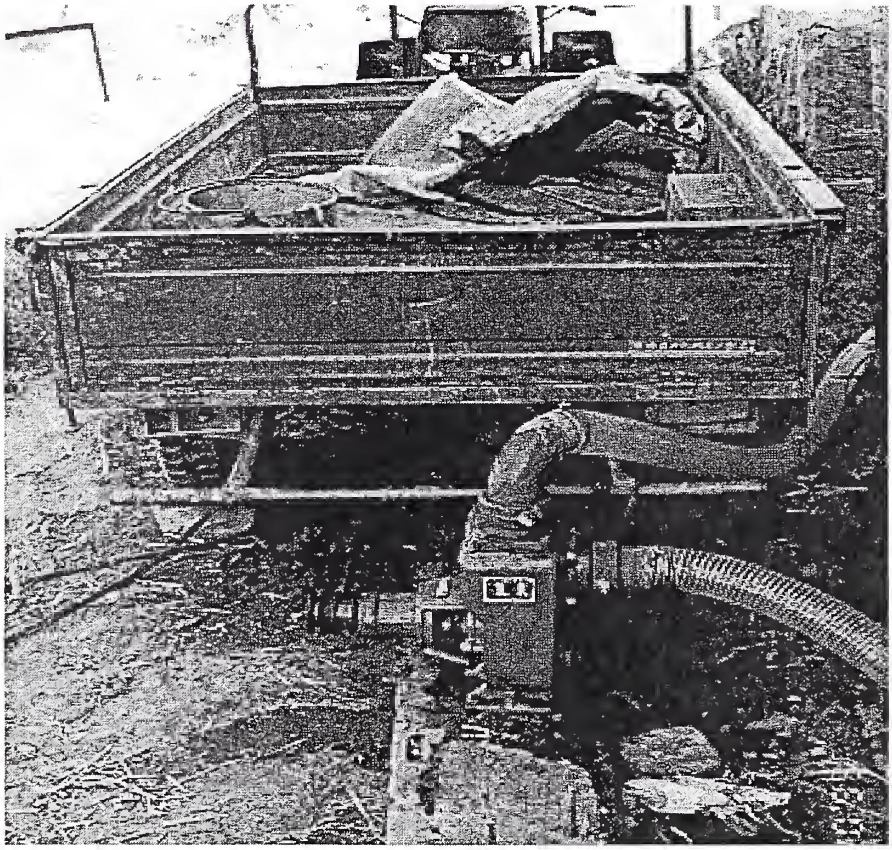
Water Saving

They plan to adopt water saving technology. They want to use spray and drip systems in their vegetable fields.

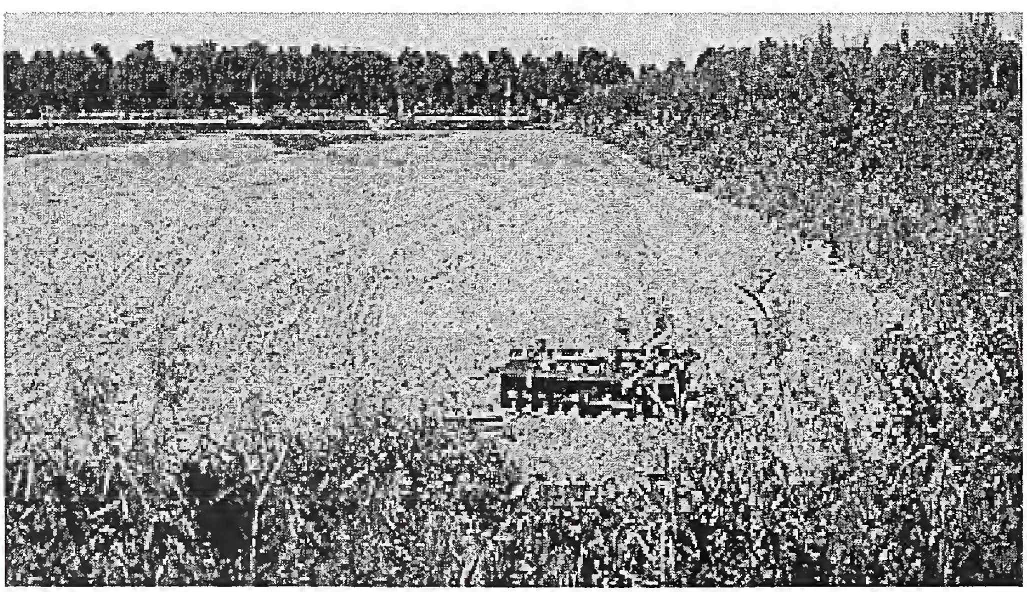
Town Industry Water Use

Industries within the town are required to drill their own wells. They have to obtain a water use permit before they can drill their wells.

Photograph 2-4--Farm family pumping water with their own power source.



Photograph 2-5—Large fields in which large farm machinery is employed to till the land



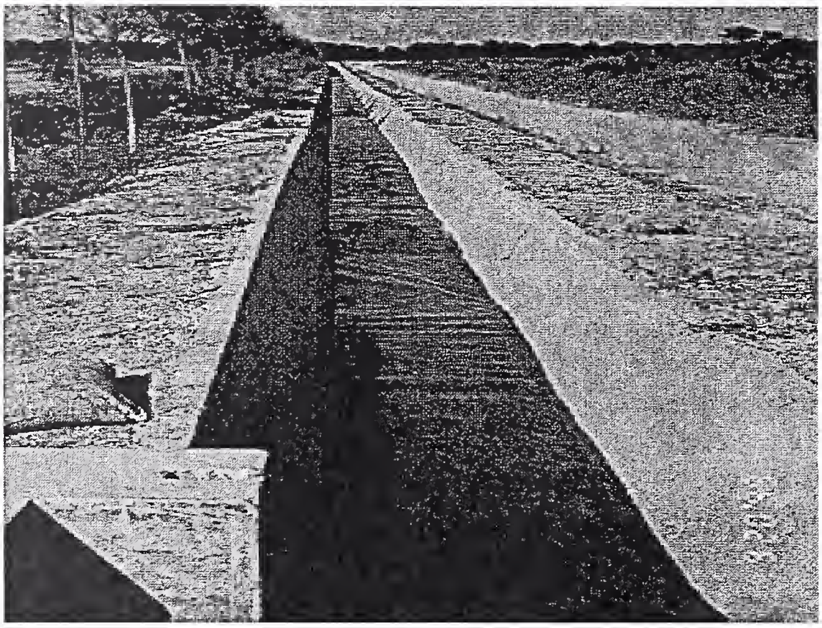
Gao Zhuang Village

Mr. Gao Tong-sheng, Party Branch Secretary, briefed the Team about water management activities in his village. The village has 4,300 people, 13 enterprises, and 2,300 workers. The enterprises include steel working, textile, food processing, chemicals, and plastics, which generated 300 million RMB in revenues. These enterprises paid 50,000,000 RMB in taxes.

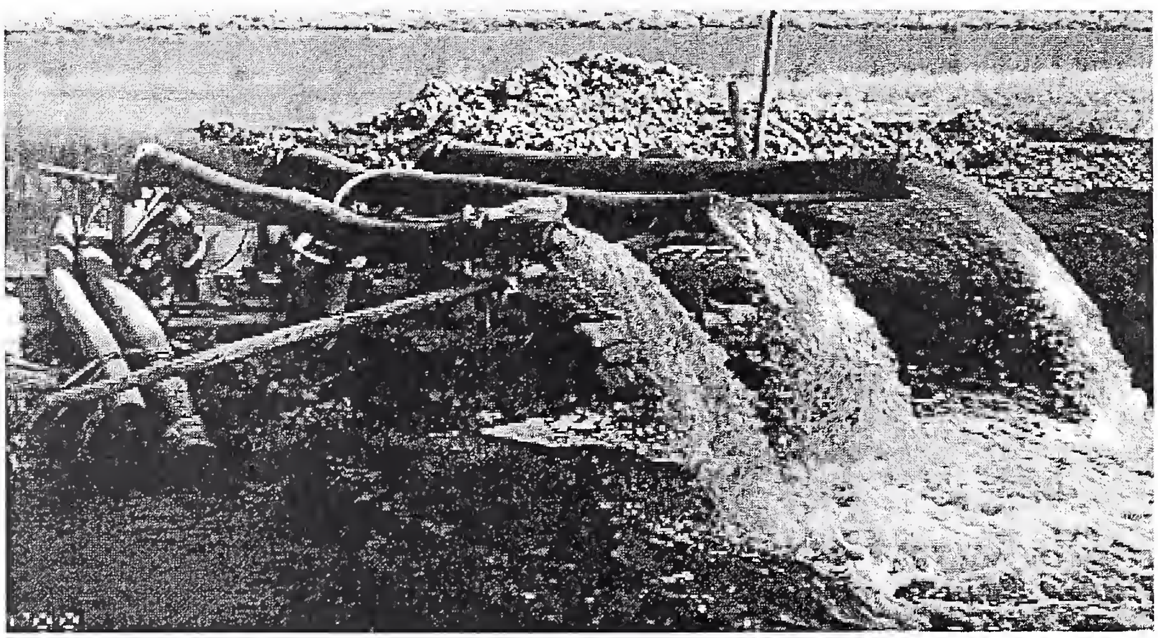
The village has 800 hectares of arable land of which 9 percent is in orchards, 33 percent in vegetables and the rest is in grain. These fields were large fields in which large equipment was used. From a map made available to the Team it looks like the village took over cultivation of what used to be an old flood plain or what once was a swamp. In other words it used to be waste land. With the improvement of flood control projects and the decrease in runoff from upstream areas the area is not very often flooded. So they took it over and farmed it using large fields and large scale machinery. The Team noted that just across the canal the fields were small. (See photograph 2-5—Large fields in which large farm machinery is employed to till the land).

In implementing the "water saving" program they lined 34,580 meters of ditches. They use 9 pumping stations to move water from the Zi ya flood canal to their fields.

Photograph 2-6--Concrete lined irrigation ditch.



Photograph 2-7--Large volume pumping station



Shaanxi Agricultural Bureau

On September 23, 1999, the Team met Mr. Gao Yuan-xiong and Mr. Lu Xi-jing from the provincial Agricultural Bureau.

General Introduction to Shaanxi Agriculture

Mr. Gao said the rainfall patterns varies greatly in the province from 300 mm per year in the north to 1,000 mm in the south. There are three climatic regions in the province: the north has a cold and dry continental climate; the middle region around Xian is in the temperate zone (apples, wheat, corn and cotton); and the southern zone is in the sub-tropical zone with rice, citrus, and sugar cane. The Qing ling mountains divide the province with water in the north of the range flowing into the Yellow river and streams on the south flow into the Yangzi river.

The province has a population of 35 million and an agricultural population of 28 million. Per capita land availability is 5,300 square meters in the north region, 1,334 square meters in the middle region and 667 square meters in the south region.

The province has 3.3 million hectares of arable land of which 1.2 million is irrigated. Only 933,300 hectares of land can be guaranteed water during drought conditions.

Bumper Grain Crop in 1999

Mr. Gao thought that total grain output for 1999 would be a bumper crop. Drought can drop grain output by as much as 20 percent in any given year. Per capita grain availability in 1998 was 370 kilos.

Mr. Lu noted that the province ranks 12th in the nation with regard to area sown to grain, 21st in grain output, and 29th in grain yields. The dryland grain crops underlie the reason for the low yields.

With regard to multiple cropping patterns for corn Mr. Lu said that there were two prime considerations. First, they want the corn to ripen early so that the crop can be taken off the fields so that winter wheat can be planted. Second they want to plant the crop so that when the water requirements are highest, that period coincides with the heavy rainfall pattern in July and August.

Mr. Lu gave the following figures:

Cultivated area	3.3	million hectares
Sown area	4.6	"
Area sown to grain	4.0	"
Wheat	1.6	
Corn	1.0	
Economic crops	0.67	
Orchards	2.0	
Apples	0.45	

Mr. Lu said that Shaanxi province is the second largest apple producer in the country. Farmers are harvesting Kiwi fruit from 7,300 hectares and have planted an additional 13,300 hectares to come on line in a few years. Mr. Lu thought that most of the orchards in the province were rain fed. Normally the government forbids farmers from converting grain fields into orchards. Orchards have been encouraged to be built in hilly areas. But Mr. Lu also noted that some farmers in the plains were converting grain fields to orchards because the returns were higher.

Water Projects

Mr. Gao said the World Bank has some water projects in the province. Most of the water control effort has been centered in the middle section of the province. Most of the agriculture in the north and in the south depends on annual precipitation.

Soil Conservation Project

Beginning in 1999 the central government will invest 2 billion RMB in a soil conservation project to stabilize the soil along the banks of the Yellow River. In the past hundred years coal has been mined in this area and miners have cut down trees for timber to shore up their mining efforts. 79 percent of the funds will be used to plant forests and 21 percent will be used to assist animal husbandry (grassland).

Forest belts in the Yu lin district have been successful in stabilizing sand dunes.

Water Saving Program

Mr. Lu reported that the province has implemented several measures to save water.

- Use organic fertilizer to build up the soil's capacity to absorb water
- Use plastic film to conserve water and raise soil temperatures
- Use of organic mulch
- Use furrows on the contours to save water (shui ping gou)
- Seed crops in the bottoms of deep furrows

The Team asked if the province was developing drought resistant varieties. Mr. Lu replied that they were working on varieties for wheat, corn, and sunflowers.

Mr. Lu said that the cost for plastic film is 7 RMB per kilo and typically farmers use about 3.5 kilos per mu. Film is used to raise corn in dry cold highland areas.

He said that water cisterns were being used. It was his opinion that the cisterns were used mainly for domestic use by farm households.

No Close Connection between the Agriculture and Water Bureaus

Mr. Gao explained that the two bureaus maintain separate lines from the province all the way down to the lowest level of government, the township.

The Agriculture Bureau has little input into water decisions. It can offer suggestions, and that is about it.

The Water Bureau allocated water between upstream and downstream users. When there is plenty of water there are few problems. But if the year is a drought year and water is short then there are great problems in the systems. In such times even the Water Bureau cannot handle the situation and the provincial governor has to intervene.

Shaanxi Water Conservancy Bureau

Mr. Liu An-qiang gave a general introduction of conditions in the province. He said there are 4,296 streams in the province of which 1,778 flow into the Yangzi River and 2,518 flow into the Yellow River. These stream drain about 10,000 square kilometers of land. The main rives in the province are the Yellow, Wu ding, Wei, Jing, northern Han, western Han, and the Jia ling.

The average annual precipitation is 667 mm, with 340 mm in the northern part and upto 1600 mm in the south. The province's water resource is 44.5 billion cubic meters of which 42.6 is surface water and 16.1 is ground water. He said return flow water was 14.2 billion cubic meters and exploitable ground water was 4.52 billion cubic meters.???

The following numbers came from Mr. Liu printed handout notes entitled "An Outline of Shaanxi Province Water Conservancy for USDA Water Team."

Water resource	44.5 billion cubic meters
Of which surface water	42.6
Under ground water	16.1
Reuse water	14.2
Exploitable ground water	4.52
Water use	8.72
Of which surface water	4.62
Ground water	3.65
Shallow	2.18
Deep	1.47

Bureau Responsibilities

The provincial government takes its responsibilities for water conservation very seriously. It has a government unit responsible for water issues at each level (province, prefecture, county and township).

The provincial Water Bureau has responsibility for managing the provinces water resources, rivers and streams, reservoirs, combating floods and droughts, water and soil conservation works. Mr. Liu said the main responsibilities were as follows.

1. Implement laws pertaining to water: water, soil and water conservation, aquatic production law, and environmental protection. It is to make relevant policies and make sure policies and programs are implemented.

2. Manage the water resources of the province. Monitor water resources and make investigations about the price of water. It should make long term water use plans. It has the responsibility to distribute water according to the water assigned to it from higher authorities. It has the responsibility to distribute water within the province. It is to implement the water use permit system and the work of collecting water use fees. It is to manage the provinces "water saving" program.

3. The bureau has the responsibility to settle conflicts arising out of water use between units in the province.

4. The bureau manages the construction of water conservancy projects. It is to make annual, medium term and long term plans with regard to water conservancy and aquatic production. It is to make water use plans for main rivers and streams.

5. The bureau has the responsibility to provide overall control and management of the important rivers, reservoirs, lakes, canals with regard to flood control and overall management.

6. The bureau has responsibility to combat floods and droughts.

7. It has the responsibility for rural water works, well irrigation, and water supplies for townships and drinking water for residents and livestock. It is responsible for managing irrigation districts and for construction facilities in farm fields.

8. It has responsibility for soil and water conservation.

9. It is responsible for urban use of underground water sources and to protect the environment of urban water supplies, and guarantee the supply of water for urban users.

10. It has the responsibility formulate policies regarding financial matters and water use fees. Under the direction of MOWR it is to provide management controls for the use of funds for water projects.

11. The bureau should establish a management system to oversee rural electrification and the construction of small rural hydroelectric plant

12. The bureau has responsibility for aquatic and fish production and for the protection of wildlife.

13. It has responsibility to resettle farmers whose land has been claimed by reservoirs.

14. It has responsibility for hydrologic work (collection of data and measurements).

15. It is responsible for science and technology, for extension and for international cooperation, for disseminating technical information, for extending information.

16. It is responsible for leading the bureau personnel in constructing water projects.

Mr. Liu said his bureau oversees the administrative hierarchy down through prefecture, county and townships.

Long History of Water Works in Shaanxi Province

Mr. Liu said that irrigation, flood control projects were built in the province in 246 BC. Irrigation projects continued including some work done in the 1930s.

Since 1949 much as been accomplished.

Item	unit	
Various kinds of water construction projects	no.	170000
Of which reservoirs	no.	1,494
With a capacity to hold	cu.m	4.485 billion
Canals	no.	54,000
Pumping station	no.	22,400
Equipped wells	no.	14,200
Spray irrigation stations	no.	597
Effectively irrigated area	1000 ha	1,410
Hydroelectric-stations	no.	2,196
Built dykes	km	5,450
Solved drinking water problems rural	million	12.68
Supplied water for urban industries	no.	270

They combined the water from large, medium and small reservoir, transferred water and pumped water and surface and ground water to supply to irrigation districts. Irrigated area constitutes 40 percent of arable.

The province has controlled soil erosion on 82,000 square kilometers about 58 percent of the eroded area.

Water Supply and Use

In a medium dry year the amount of water is:

Surface	4.62 billion cubic meters
Of which stored water is	1.44
Transferred water is	2.49
Pumped water is	0.79
Underground water is	3.65
Shallow wells	2.18
Deep wells	1.47
Total	8.27

The use of water is as follows:

Agriculture	5.77		70% of total use
Industrial use	1.53		19
Domestic use	0.92		11
Total use		8.15	100%

Underground Water

In the northern part of the province the shallow ground water is from 2 to 8 meters; middle part it is 8 to 40 meters; and in the south it is 2 to 20 meters.

They consider deep wells to below 200 meters. At 1,000 meters the water temperature is hot.

Overdrafting of the underground water supply is occuring in the Guan Zhong plain (the area around Xian). In that area there are deep wells to supply urban and industry use water for the Xian area. We think Mr. Liu said that some of the agricultural wells in the area have dried up as a result of the falling water table.

Irrigation

Mr. Liu said that 69 percent of irrigation water came from surface water sources and 31 percent came from ground water.

With regard to irrigation methods, Mr. Liu said, farmers in the province water 65 percent of their fields with small rectangular fields bounded by small levees (xiao qi guan gai), 15 percent use spray and drip systems and 20 percent use flood irrigation (man guan) method.

The Setting of Water Use Fees

Relevant offices in the provincial Water Bureau such as the financial office, and the price office fix the price. The bureau makes investigations, prepares analyses for use in setting water prices. (We did not get a clear picture of how all of this happens).

Water Use Permits

Mr. Liu said that entity seeking a water use permit makes an application, which is submitted to the county water bureau. If the request is small and it is within the parameters set by the province, then the county bureau can issue a temporary permit to drill a well for example.

The user must find a licensed well drilling company. The bureau sends staff out to check the quantity and quality of the water from the well. If everything is in order then the final use permit is issued.

Relationship between Yellow River Commission and Shaanxi Province Water Bureau

Mr. Liu noted that for streams, which are wholly within the boundaries of the province, they are in control. If a stream or river comes from a neighboring province then the Yellow River Commission gets involved.

The commission allocates a quota of water to Shaanxi province. See chapter 3 for details.

The Jing Hui Irrigation District

Mr. Lei Tian said the irrigation district was formed in 1932. It serves an area of 86,670 hectares of land. The headquarters for the district is in San Yuan County seat, but five counties are in the district. This being the case, then the provincial water bureau is involved with this district.

Three rivers pass through the district: the West Jing river, which enters the Wei River downstream in the district, and the Qing River in the northern part of the district. The district has a total of 385 kilometers of canals.

The total staff of the district is 670, with 170 retired workers. The district has one office and 6 divisions, 14 management stations, and 10 enterprises (i.e., a cement factory). Fifty percent of their staff works in the 10 enterprises.

Long History of Irrigation in the Area

In 246 BC Qin Shi Huang began diverting water to this area. His men (Zheng Guo) built a diversion dam up stream on the Jing River and constructed a canal to bring water down into the valley. Subsequent dynasties, the Tang, Sung, Yuan and Ming pushed the diversion dam further upstream. In 1932 a dam was built on the river to divert water into the canal system but a flood in the 1960s washed it away. Construction on the present dam began in 1992 and completed in 1997. The dam has two flood spillways and six sluice gates. The dam is 450 meters above sea level.

Operation of the District

The district has 14 stations, which manage the water to the main lateral ditches. The next layer down is the ditch mangers. At the village level there is a water master (shui guan li ren). The staff in the stations are government employees and are paid by the provincial water bureau. The ditch managers and the village water person are not government employees and so some of the money collected in water use fees goes to pay their wages.

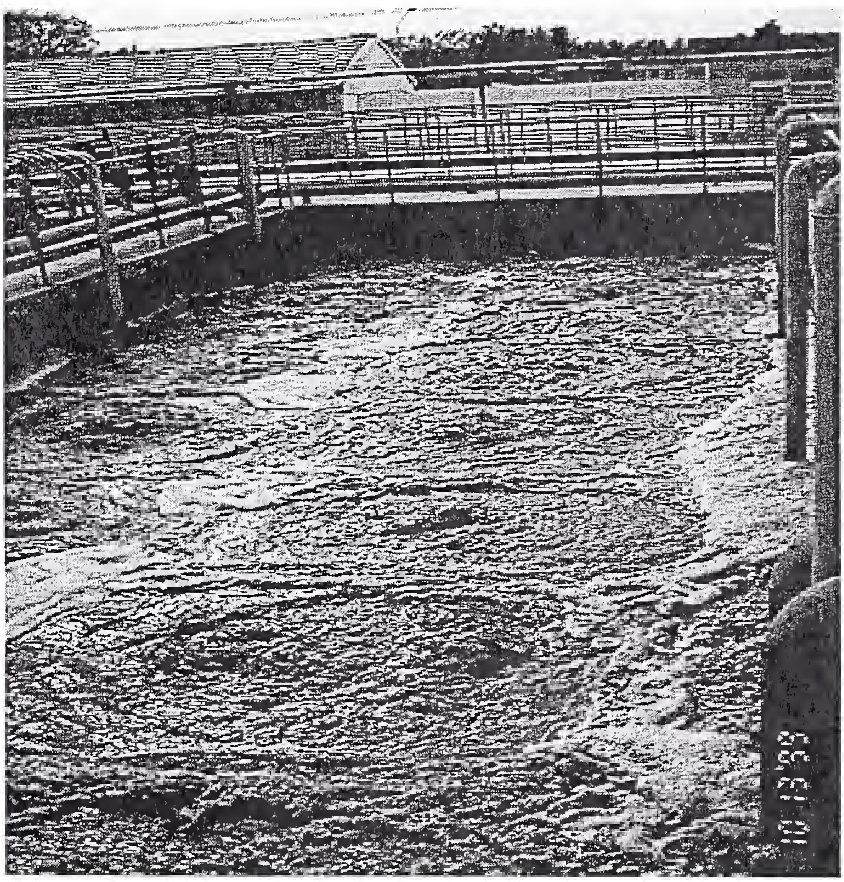
The adult rural population has to allocate 30 days a year to work on public projects. Farmland construction, and road construction and maintenance are allocated a given

number of days. In Shaanxi Province farmers are supposed to spend 7 days of their 30 working on water projects. Mr. Lei said that the labor assignments come from the county, to the township, and then to the village. The workers are used to clean out the silt and weeds from the ditches.

Visit to Beijing San Yuan Dairy Plant

On October 13, 1999, Frederick Crook accompanied the USDA Dairy Product Consumption Team to the San Yuan dairy processing plant located near the Shuangqiao state farm. The plant managers gave the team a tour of their water treatment plant which the local government made them construct to process the effluent discharged from the processing plant. The treatment plant was in operation and Photograph 2-8 shows one of the processing tanks.

Photograph 2-8—Water treatment facility, San Yuan Dairy Processing Plant



Chapter 3

Water Policy and Policy Implementation

Xinshen Diao

In China, water resources are managed by the MOWR, a central government agency charged with water policy making and policy implementation. After the adjustment of the government administrative organizations in 1998, the functions of MOWR in direct investment have been weakened while its role in providing regulations, rules and management according to the laws made by the National Congress have been enhanced. While the government priority regarding to water issues ranks first as flood control, urban water use, industrial water use, and then last irrigation, the water resource management and protection are becoming more and more important for the central government.

Water Resource Management

China has water resources of 2812.4 billion cubic meters in an average year, 2400 cubic meters per capita. The regional distribution of water resources is not even. Water resources include mainly rainfall, surface runoff water and groundwater. The Chang River basin and south of Chang River area are water resource abundant regions with 81 percent of national water resource and 46 percent of national population. The north part of China, mainly Northwest China and North China Plain, has less rainfall and surface water. In some areas, such as Northwest China, underground water resources is also not rich. Thus, the north part of China is identified as water shortage area. These areas have more than 60 percent of national farmland with only 19 percent of national water resource. In addition, in most areas, both in the South and North, the rainfall season is in summer months while winter and spring are quite dry. Hence, both flood and drought occur frequently and a serious flood or draught occurs in the country almost every year.

The comprehensive management of water resources has been further emphasized by the government in recent years due to the development of water shortage and deterioration of water environment and water quality. The principle of water resource management is summarized into six Chinese compound characters, told by a division chief from MOWR. The English translations are: 1) development of the water resource availability; 2) utilization of the current water resources; 3) water conservation and improvement of water resources; 4) allocation of the water resources; 5) water savings; and 6) water protection. A division chief from the Water Resource Bureau, MOWR told us that the utilization rate of water resources is about 19 percent currently in China, while it varies across regions. The rate is the ratio of water used over total available resources. With such a low average utilization rate, officials believe that China has the potential to improve its development and use of its water resources. However, in North China, this rate is much higher than 40 percent, and reaches 80 percent in some areas such Beijing and Tianjin areas.

We were told that according to the UN's standard, when the rate is more than 40 percent, the water environment starts to deteriorate, such as rivers running dry before entering the sea as normal, subsidence, sea water intrusion and water pollution. In water over-used area, one of the major tasks for the water resource manager is to control water use, especially for the over drafting of underground water, and to find new source of water to replace the current ones. In the meantime, water saving and pollution control are also among the task of water management.

Water Use Permit Policy

Central government's water policies are mainly embodied in a series of laws and regulations issued in recent years. After the water law was issued by the National People's Congress in 1988, a series of water resource management and water conservation regulations and rules were issued. The most influential policy is the implementation of the State Council's regulation about issuing water use permits. This regulation was issued in 1993, while a monitoring and managing measure to guarantee the implementation of the regulation was issued by the MOWR in 1996.

According to the regulation, users (including individuals and institutions) cannot draw water from any river, lake or underground source without obtaining a water use license. The government water resource management agencies at each level have the right to issue a license to the water user. The Water Resource Management Division, one of the divisions in the Bureau of Water Resources, MOWR is in charge of the management of this system, such as to make decisions on the contents of the license, to assign licensing rights to each level of the water management bureaus, as well as to print the certificates. Different levels of water management agencies can permit different drawing volumes of water. For the river basin commissions, there are rights to permit a large volume of water drawing from the rivers or underground within the river basin. There are seven such commissions as local arms of the MOWR in the seven major river basins. For each example, if water is drawn from a gauging station along the main stream of Chang River and the daily withdrawal is more than 150,000 cubic meters, the license has to be issued by the Chang River Water Conservancy Commission. However, for the Yellow River main stream at its middle and lower reaches, a relatively small drawing amount has to be licensed by the Yellow River Commission.

The Commission also has the right to permit the drawing of underground water within the Yellow basin. The water bureaus in the provincial governments have the right to permit relatively smaller volume of water withdrawal. The much smaller volume of withdrawal, such as to dig a well, is approved by the local government's water bureau. For example, if a village wants to dig a well, the village chief needs first contact the water station at the township level. The water station submits the application to the county's water bureau. The location of the well as well as the withdrawal volume has to be approved by the county's water bureau. Once the application is approved, the village is permitted to dig the well and hence a licensed drilling company is hired to conduct the construction. When the well is finished, the county bureau has to check whether the well is in the right place as well as the depth of the well. If every thing is consistent with the plan, then a

water use license is issued to the water user. The county's water bureau will monitor the amount of the water drawn from the well by annual evaluation or water drawing measurement.

There are some irrigation district management bureaus in each province. They manage and deliver the water in the irrigation canals. However, these bureaus still need a license to draw water from a river or underground. That is, the irrigation district bureau is treated as a water user, for which the amount of water that can be drawn from the river or underground is also monitored by the Water Resource Bureau.

The water withdrawal permission policy has just been implemented in the last few years. For the officials from MOWR, it is believed that even though in some remote rural areas, there may be some wells drilled without a license, it is hard to find many counties in which all wells were drilled without a licenses. Moreover, since urban or industrial sector who use underground water have to pay water resource fee, besides the water delivery cost, and the water resource fee can be used to cover expenditures of water management, through the management of the financial bureau in the same government level, the water resource bureau has motivation to monitor the implementation of the regulation. However, we were told by the researchers from CAAS, it is quite common in rural areas that farmers drill wells without any permission.

Underground Water Management

Underground water accounts for 1/6 of total water consumption both for the total use and irrigation. In North China area, ground water irrigation areas account for 60 percent of total irrigated farmland. In the past, underground water was managed by two different ministries. Besides MOWR, the Ministry of Geography and Mining was another central government agency to manage the underground water. In the recent government organization re-adjustment, the MOWR was named as the only agency to manage the ground water. The overdrawing of the underground water is quite serious in many areas of China, especially in North China. There are more than 56 underground cones of depression with an area of 87,000 square km. The deepest ground subsidence in Beijing is about 0.8 meter and 2.6 meter in Tianjin. There are various reasons for forming these underground cones. In some areas, it is mainly due to the development of urban area and urban industry, such as Beijing and Tianjin, the two largest cities in North China. The rapid growth of rural industry and urbanization is believed to be the main reason for underground water overdraw in the area of Su-Xi-Chang (Suzhou, Wuxi and Changzhou in Jiangsu Province), one of the most developed rural areas in China's coast region. The overuse of underground water for irrigation in Cangzhou area, Hebei Province may contribute to the formation of a deep underground cone there.

However, there is not enough national wide information about the overuse of underground water. A national wide survey about underground water resource situation is going on and will be finished by the end of this year. Through this survey, the MOWR wants to fully evaluate the underground water resources, including the location of ground water overdrawing areas and the reasons for the overdraw.

While the survey would help the policy maker to manage the ground water resource, the current policy already starts to control the use of underground water in the overdrafted areas, especially for over drafted deep aquifers. The basic principle is to use surface water instead of ground water, if there is source of surface water. In some overdrawn areas, such as Hai River Basin and Su-Xi-Chang area, users are not allowed to drill new wells and are limited in drawing from current wells.

In the all places that the Team visited, local government and water management agency officials were aware of ground water use policies. However, the understanding of the policy is different. At the municipal level, we were told that the new well is strictly controlled and the number of wells is not allowed to increase in Tianjin area. However, in rural areas of Tianjin, the government officials from two townships told us the control is for the use of deep aquifer, while the use of shallow ground water is still encouraged. It seems that the restriction is dependent on the recharge capacity of the ground water. If a shallow aquifer is naturally recharged through rainfall, the control on the use of the shallow aquifer is not that strict. In terms of deep aquifer ground water, we were told by the local government in each place we visited that it is only used for rural domestic use or rural industrial use. The costs for drilling wells and pumping water from the deep aquifer are too high for irrigation. However, with the development of rural industry, there is still potential to increase use of deep aquifer's ground water in many rural areas. Moreover, if increase in grain production is a policy priority for a local government, deep ground water still could be used for irrigation without considering its cost.

Water Use Priorities and Government Investment

Flood control is ranked as the priority for water management in China and a major part of central government investment funds are used in this effort. One of the major reasons is that there are many large and medium sized cities along the large rivers such as the Chang and Yellow Rivers. Flood control actually focuses on the protection of urban areas of these cities. In terms of water use, while agriculture uses 70 percent of annual water resource, urban and industrial water consumption has been increasing rapidly with economic growth. The urban and industrial water use is ranked as the second priority position, which is mainly reflected in the funding distribution of the central government's investment.

While the gap between water supply and demand received increasing attention from the central government, the main concern is for the shortage in the urban and industrial use. There are a few water transfer projects underway at the provincial levels, such as Zhang Jia Zai project conducted by Shanxi Province, the large scale of the South-North water diversion projects are still at the stage of discussion and evaluation. The policy emphasis to deal with water shortage is on water savings and control of the overuse of ground water.

Most water conservancy investments reflect the implementation of government's policy priorities, as the government is the decision-maker for all large investment projects in

China. In practice, the large or medium size investments are called as infrastructure investments and hence have to follow the same application and approval processes as other infrastructure investments in the other sectors. These large projects, such as building a large reservoir or dam are often applied for by the provincial government, sometimes through MOWR. The projects have to be approved by the State Planning and Development Commission. Allocation of the central government's funding to water conservancy investment in recent years clearly shows the policy priorities of the central government on water issue. For example, in 1997's total water conservancy infrastructure investment, the investment on reservoir accounted for more than 30%, flood control by dam protection and improvement, 16%, hydropower 24%, water supply to urban area 10% and irrigation 10%. The total infrastructure investment amounted to 31 billion in that year, among it, 25% from central government fiscal budget, 15% domestic bank loan, 10% foreign loan and the rest from local governments or project investors.

Irrigation Investment

As irrigation in the government priorities is ranked in the last position with regards to water issues, the government funding spent on irrigation projects is relatively small. Back to1980s when the economic reforms started, the MOWR was in charge of all large and medium size water investments, including irrigation projects. After the reform, the budget as well as the use of the budget for irrigation is reallocated from the central to provincial governments. Thus, during 1980s and early 1990s, no irrigation investments were made by the central government. With the deepening of the water crisis as well as the re-emphasis of grain self-sufficient agricultural policy in 1994, the central government, through the MOWR, started to allocate some fiscal funds to irrigation projects, especially water-efficient projects in latter part of the 1990s. In 1996, there were about 1.5 billion RMB fiscal funding allocated for irrigation related projects, mainly through interest subsidies for bank loans. Some amounts of similar funding were allocated in 1997. In 1998 and 1999, Premier Zhu decided to finance irrigation projects by issuing the State Treasury bonds. In 1998, such government bonds amounted to 0.8 billion and 1.25 billion RMB in 1999. In the meantime, provincial and local governments also increased financial support for water-efficient irrigation projects. During 1996-98, total investment in water-efficient irrigation projects by local government amounted to 5 billion RMB per year on average. However, compared with around 30 billion RMB of investment in building large reservoirs or dams, irrigation investment is still limited.

The allocation of the central government's investment fund on these irrigation projects is conducted by MOWR, and the fund is mainly used on the large and medium sized projects. There are more than 150 major irrigation projects under which the irrigated area produces about 60 percent of China's total grain. The new government investment is aimed at creating a long-awaited upgrading program for aging irrigation projects in these major irrigation areas. The investment still focuses on the surface irrigation, such as channel lining or pipelines. It is believed that only 40 percent of water is used efficiently during irrigation. Most water was lost due to the use of water-consuming flooding

irrigation methods, aging irrigation facilities and serious leakage in most trunk and branch canals, the majority of which were built between the 1950s and the 1970s.

From MOA we were told that so far about 28 percent of country's total irrigated areas have adopted the so-called water-efficient irrigation technology. The target of the government is to increase this number to 58 percent by 2010. The final goal of the program is to increase irrigation areas by reducing waste. Hence, each project is designed to bring water to at least 20,000 more hectares of fertile farmland, and total irrigated area is targeted to reach to 57 million hectares, or 43 percent of total farmland.

The definition of water-saving irrigation is quite flexible. According to the MOA, about 97 percent of irrigated areas still are using traditional method, i.e. the surface irrigation. Among the 53.3 million hectares of irrigated cultivated land, the so-called water saving irrigation method covers about 15.3 million hectares. However, among this 15.3 million hectares of land, reducing water leakage by canal lining accounted for more than 50 percent, about 8.67 million hectares, while the low-pressure underground pipeline accounted for only 5.3 million. The sprinkler irrigation accounted for 1.2 million hectares and 267,000 hectares used the micro irrigation method. The sprinkler irrigation is concentrated mainly in north of China and mainly used for cash crop production such as vegetable. However in Beijing where farmer's labor cost is quite high, sprinklers are used on grain fields.

From our field trips we also noticed that most so-called water-saving irrigation simply implies canal lining. However, most ditches, i.e., small canals in the crop field are still dirt ditches. In Beijing where the water-saving irrigation area accounted for 70 percent of irrigated area according to an official from the Municipal Water Bureau, the major water-saving method is still canal lining, accounting for more than 50 percent of so-called water-saving irrigation area. The low-pressure underground pipeline that can reduce water leakage in small ditch is still not popular there. Moreover, the irrigation method in the crop field is still dominant by the traditional way, i.e., flood irrigation, and even in the area where the low-pressure underground pipeline already have replaced traditional open ditches.

It is obvious that the investment on the water-saving irrigation methods are going to improve the physical and technological conditions of the current irrigation system in major irrigated area, which helps to increase irrigated areas with more efficient use of water. However, with the increase in irrigated areas, total demand for water will not fall but actually will increase.

The water lost during transportation can partially become underground water. With the efficient water transfer and the expansion of irrigated area, the potential effects on total water resources, surface plus ground water, is unclear and there were few discussion about it in China.

Demonstrating Water-saving Technology

While the major portion of the water-efficient irrigation program is allocated to the improvement of surface irrigation facilities in major branch canals, the new technology and more efficient irrigation methods are also important for water savings. For this purpose, a small part of government funds is allocated to the construction of water-efficient irrigation experimental projects. There are about 130 such projects in large crop-growing areas. These projects will serve as models, demonstrating how to increase farming economic efficiency through adopting water-saving technology. The funds for the water-saving farming projects are allocated to each province in the irrigated areas and then finally allocated to one or two villages in each province. Several different water-saving irrigation techniques are demonstrated on selected farmland, such as fixed or portable sprinklers, drip, micro irrigation, low-pressure pipeline irrigation or surge irrigation. Each village may only undertake one or two of these techniques. The funds from the government for the demonstration field are used to purchase irrigation facilities or other technical equipment such as software or computers, while farmers provide farmland, labor and pay electricity costs.

These demonstrated techniques are indeed water saving. However most of them need some necessary conditions that may not exist for most villages, especially those dominated by small household farming system. First of all, some techniques such as sprinkler irrigation are only feasible for large sized fields. The demonstration fields are hence chosen in a village where the size of each piece of farmland can be beyond the household's contract land. They can be part of land owned by a collective farm, such as Xu Xin Zhuang township in Tong County, Beijing and Shui Gao Zhuang village in Xi Qin County, Tianjin, or is farmed by a specialized team even though land is still owned by each individual household normally, such as in Wu Qing County, Tianjin. These kinds of large scale farming system however only exist in the suburban areas of large cities or in the highly developed coastal regions. In these regions, the opportunity cost of agricultural production, especially grain production is very high as well as the opportunity cost for water. The more efficient use of water in these areas should be in nonagricultural sector, or high value added agriculture. Hence, it is expected that water supplies for agricultural, especially grain production in these regions will become less and less. It is doubtful that the techniques demonstrated in these areas can become standard practice in the near future for small farmers that dominate China's grain production.

Second, many water-saving techniques involve capital investment and some equipment that is quite expensive for small farmers, such as drip irrigation equipment. At this stage, the facilities are usually provided by the government freely to the demonstration village. It is for sure that almost no small farmer can afford to buy them, while it is also impossible for government to provide them to all farmers. A few farmers may buy them, but will mainly use them for high value added crops, such as vegetables or fruits supplied to special users such as hotel, restaurant or high level super markets. Water may be used more efficiently for these high value added crops by adopting these techniques. However, the majority of farmers are grain producers and grain consumes the largest part

of irrigation water. Without broad acceptation by grain producers, the economic value of the water-saving equipment is quite small for real water-savings.

To utilize a new water-saving technology or equipment one needs knowledge and a certain degree of education. Given current farmers' education level in China, the extension of most of these new techniques or equipment is questionable.

Finally, the most important condition is that farmers have to have a motivation for water saving. If water can be almost freely used, farmers have no intention to adopt a new irrigation method. Even if the government freely provides the new equipment, the water can still be largely wasted by using this new equipment. For example, we are told that farmers can turn on the sprinklers for a whole day, which resulted in more water used than with the traditional surface irrigation.

While the water pricing issue will be discussed later, the education of local water shortage situation to farmers is also important. Some simple graphs that are easily understood by farmers can be used to describe the historical change in underground water in the area where farmers live. With awareness about the water shortage directly related to farmers' living and crop growing conditions, farmers may enlarge their understanding of water-saving ideas. Even using traditional surface irrigation methods, water can be used more efficiently if farmers have the motivation to reduce the use of a scarce resource.

The efficiency of the government investment projects is also questionable. The government funds are hardly fully used on water-saving technology and related facilities. Part of the investment funds can be easily converted to the benefit of water resource management agencies. In Xu Xin Zhuang, Tong County, Beijing, the office building for the Water Management Station which has only 10 staff members was larger, more modern and nicer looking than most township government offices. As the allocation of the government funds to the experimental and demonstrative study in the village farmland are through the Station, it is not too hard to figure out where the money for constructing the office building came from.

Moreover, the water transfer channels which connect farmland by small ditches, is out off the consideration by MOWR, as most of these projects are quite small. In addition, there is less consideration for the efficient use of water by farmers, since all agricultural related issues are out of the responsibility of MOWR and belong to the MOA.

There are some other investment projects promoted by MOWR in rural areas. These projects include water supply for domestic use by rural households and the construction of a new irrigation system for low-yield farmland. However, all these projects are small-scale and many of them involve farmers' investment. Hence the government spending is often in the form of subsidies on farmers' investment. For instance, if farmers want to dig a well, the local government may provide a 300 RMB subsidy, while farmers' total cost may be more than 10,000 to 25,000 RMB.

The amount of these investments, including the farmers' part, either through labor contributions or equipment purchase is estimated to be about 30 billion RMB annually. Such investment does not necessarily result in water savings, instead, it will increase water use as water becomes available for more users. Moreover, once a well or a small reservoir is built, the cost of water use for farmers is only the costs of pumping or delivery fees. Thus, the over-exploitation of underground water can be a possible outcome of such investments as too many wells are dug. This already becomes a serious problem in North China plain. Even though to drill a well has to be formally approved by the government according to newly issued water laws or regulations, it is not difficult to obtain approvals. Moreover, the implementation of this law in remote areas is still difficult and quite often the law or regulation is not followed.

Water Pricing Policy

Another important water policy in recent years is the reform on water pricing. It was realized that price for water used by both urban and rural users was low. Actually for a long time before 1980, water was used almost freely. In recent two decades, water price was raised many times, almost once every other year. The principle of the current water pricing policy is to meet its maintenance and operational costs, while for water shortage area, an additional water resource fee, especially for ground water has been adopted for urban users. The central government, through the authority to MOWR, has issued a few regulations or rules regarding to the water pricing. The basic requirement is that price of water used by industry and urban residents should be slightly above the water delivery and facility operational costs with provision for a small profits, while the price for irrigation water should cover these costs. There is no clearly defined water use rights concept as well as less consideration about the shadow price of water when water becomes scarce. Aside for the growing concern about the gap between water supply and demand one of the major considerations for the government is its budget constraint. With a decline in government revenue as well as the adjustment of government's function in the economy, almost all reservoirs and major water transfer channels built by the government cannot have enough funds to cover their maintenance and operational costs. Moreover, as most of these facilities were constructed during 1950s to 1970s, the aging equipment is becoming more serious. The central government wishes to increase the water price to lessen the pressure on the water industry as well as water demand.

The actual implementation of water pricing is carried out by the provincial government, which mainly decides prices for water delivered from large and medium size reservoirs or transferred through main channels. For the water from small reservoirs, wells or canals built by a township or a village, its price is decided by local water bureau even by farmers themselves with various methods. Given the complicated situation among different regions and across different users, it is impossible for the central government to make a uniform price for the country and hence the real pricing rights are assigned to the provincial government. The Price Management Bureau at the provincial level is the government agency, which fixes the water price, while the Water Management Bureau helps the Price Bureau to calculate the water delivery costs. In practice, there are only a few provinces where water price can cover total cost of water, including capital

depreciation costs. For some provinces, water price can cover the maintenance and operational costs, while for most provinces, the price is still too low to generate enough revenue for facility replacement or new investment project. The local government's priority and preference become a major principle for each provincial government to price water. On average the water price is about 50 to 70% of water total costs, which can hardly cover the operational and maintenance costs. At the present, replacement of current facilities and new investment projects for large- or medium-size reservoirs and main transfer channels are still financed by the government.

Underground water accounted for one-sixth of water resources both for total and irrigation use, and is mainly used in the north Yellow River area. Underground water pricing policy is as similar as that for the surface water, i.e.; the price is decided by the provincial or municipal governments. However, given the shortage of underground water in many regions, especially in North China plain, some amount of water resource fee is included in the price for the underground water used by urban citizens or industry. For agricultural irrigation, there is no water resource fee for underground water yet.

During our field trips, we understand some basic method to collect water charges. For example, in Miyun Reservoir Management Bureau, we were told that collection of the charges is done at different water delivery levels. Miyun Reservoir is the largest reservoir near Beijing, supplying all water to Beijing urban area as drinking water or industrial use. The water charges are collected at three different delivery levels. The water is first delivered to two smaller reservoirs and the volume of water going to these smaller reservoirs is metered. The management division, which is an independent accounting unit, pays to the bureau for the water coming to the smaller reservoirs. Then there are two main canals connected with the smaller reservoirs. At the head of each canal, water is metered and the canal management branch, which is also an independent accounting unit, pays division for the water delivered into the canal. When water is delivered to the final users, such as Beijing Water Supply Company, the major suppler for city water use, the company pays to the canal management branch for the water delivered to the company.

The government priority on other economic issues also limits the increase of water price. In China, the achievement of provincial government is mainly measured by the economic growth in local area. A high water price may affect some industrial sectors' growth if they use a lot of water, such as textile, mining, chemical or steel industries. Moreover, as many state-owned enterprises are already in difficulty during the economic transition process, a high water price may generate further problem for their surviving. A high water price is also not welcomed by urban citizens, since their income growth has started to slow down in recent years.

The current agricultural policy is another major factor to constraint a rise in water price, especially for the water used in grain production. Under the current governor's grain production responsibility system and the re-emphasis on grain self-sufficiency, grain production is actually an important political indicator to measure the achievement of local government. Water may have a high opportunity cost in grain production in many areas,

especially among the more developed regions. However, in order to keep a growth in grain sector, most local governments have to keep a low price for irrigation water, which becomes an implicit subsidy on agriculture.

In some provinces, governments have price discrimination policy for water use in different agricultural activities. For example, water used in fishponds or orchard is charged at a high price while water for grain production is low. Even though water opportunity costs are lower for grain, in many regions it is still the major choice of crop on their farmland. The rise in water price would affect farmers' income, which becomes another constraint for local government hesitating to adopt a new water pricing policy.

There is another more complicated problem that has been less considered in current China's water pricing policy. Most of current water projects were built during 1950s to 1970s under the central planning regime. Farmers as final users were not included in making the investment decision. With such an economic system, the efficiency of these investment projects was questionable. The costs that farmers asked to pay are accounting costs calculated by the planners, regardless of the market value of the project. If a project is a low efficient one or built based on a wrong investment decision, farmers now actually are asked to carry the burden if they are asked to pay water price since they have no other choice in terms of water use. Moreover, for most water projects, farmers are major labor supply. Under the old collective agricultural production system, farmers provided the labor for construction of the projects. While even in the recent years, each rural laborer is asked to provide 25 to 30 days freely to the public projects, including water projects. Such labor cost may not be counted as part of the investment costs or calculated according to traditional planning economic method, and hence may under-estimate the contribution share of farmers. This problem further indicates the difficulty in China to form a water pricing system as well as to establish water use right concept and develop a water use right market, as used in some countries now.

Water-saving Farming Techniques

Water-saving farming and irrigation techniques is also encouraged by the central government as well as by the provincial and local government for the growth in grain production. In general, the extension of water-saving irrigation technology by introducing new machinery or other equipment is done by the Water Resource Management bureau at each level of the government. The extension of water-saving farming technology as well as the introduction of anti-drought crop varieties are the responsibility of the Agricultural Bureau at each level of the government.

One of the water-saving farming methods in rice production was mentioned both at MOA and Tianjin Agricultural Bureau. This new method called "shallow, wet and dry" is replacing traditional irrigation method that keeps deep water in paddy rice field and also for a relatively long time. Using this method, water use can be reduced by 1,500 to 6,000 cubic meters per hectare, while yield of rice roses by 750 to 3750 kilograms per hectare.

Tianjin used to have 100,000 hectares of paddy rice in 1960s. Paddy rice mainly depended on surface water for irrigation. Due to the reduction of river water outflows in the Tianjin area, rice area was reduced to 33,330 hectares in the1980s. In recent years, due to the adaptation of water-saving farming methods, together with the extensive use of water storage methods, rice area increased from 53,330 to 66.670 hectares. The new farming methods can reduce paddy rice's water demand by 30 percent per hectare, while yield rose from 4500 kg in 1980s to 7,800 to 8,250 kilogram currently. The water-saving farming methods are also extensively used by other grain crops in Tianjin, such as 146,700 to 153,330 hectares of wheat and 160,000 hectares of corn. The spring corn is one season dryland crop and mainly depends on rainfall. To change the sowing time of spring corn from April to May can allow the crops' most water demand time period is delayed to July when there is enough rainfall.

Farmers in North China extensively use water storage methods, both in irrigated area and dryland area. In some areas of Tianjin, some reservoirs are built to store rain water in the plain area, while in many areas, farmers just use current canals, rivers or ponds to store summer water. There is plenty of water during summer in most places of North China both due to rainfall in the local area and in the upper reach areas. Once abundant summer water is stored, it can be used during spring when crops need more water but the weather is often dry. This method was talked about by officials from water and agricultural bureaus at the municipal as well as from local government officials in counties, townships and villages. Thus, it seems that the method is extensively used in Tianjin area, where the land is quite flat and water storage is feasible.

The water storage method allows agriculture to develop its own irrigation water sources. In both Beijing and Tianjin, the water sources for urban area and rural area are relatively independent. For example, water from Mi Yun reservoir is only supplied to urban area, while the water diverted from Luan River to Tianjin is only for the urban area too. The surface water available for irrigation is from rivers, together with the reserved rainfall waters by some small reservoirs. In these two areas, underground water sources for urban and rural are also independent. While shallow ground water is used for irrigation, and deep ground water is for urban and mainly as drinking water. The overlap in the use of these two levels of ground water is mainly for industry, which uses both shallow and deep ground water.

Dryland Water Saving Agriculture

Among the 126.7 million hectares of cultivated land in China, about 70 percent are dryland. Dryland is usually in an area that has almost no access to irrigation facilities. Agricultural demand for water mainly depends on rainfall. Dryland areas are mainly located in Northeast (18 percent), Northwest of China (19 percent), Loess Plateau (35 percent), and the North China Plain (28 percent). There are more than 24 provinces and almost 1000 counties where dryland agriculture is dominant. (See the map on page). Rural poverty is commonly related to the shortage of water in China. About 2/3 of China's poor counties are located in dryland area with low crop yields and less development in the whole economy. In most dryland areas, there is insufficient surface

and underground water as well as rainfall. Moreover, only 10-20 percent of rainfall comes in spring when water is more needed by crops, and 40 percent during summer. The irrigation facility and technology are quite backward and the utilization rate is below 40 percent in most places. With less water, more than 50 percent of cultivated land has poor quality. In these poverty areas grains are the main crops for survival and other crops get less attention. This further damages the ecological environment and hence grain yield is quite low, about 3.6 tons per hectares, more than 450 kg lower than national average.

Dryland areas are mainly located in north of China, where wheat and corn are major grain crops. About 46 percent of grain in the country, 61 percent of cotton, 72 percent of soybean and 46 percent of oilseeds are produced in dryland areas.

While there are many disadvantageous conditions for agriculture in dryland area, there is potential there too. Given China's land constraint, irrigated areas have a high population density and most of the land surface is cultivated there. For example, in the East Coast of China, a major irrigated area for agriculture, there are only 267 square meters of cultivated land per capita. The potential to improve yields is sometimes regarded as small because the land has been tilled for over 2,000 years. On the other hand, the land area per capita in most dryland areas is much large. For example, the per capita land in Northwest of China is about 0.53 to 0.6 hectares. Except for water, many other natural conditions are suitable for agriculture in many places among the dryland area, such as weather and long day length.

Developing dryland agriculture is hence to be believed by the government as a strategic choice for China's economic development and agricultural growth. Moreover, the improvement in agricultural and ecological conditions in dryland areas help to reduce soil and water erosions, which would benefit flood control and environmental protection. In terms of cost-benefit analysis, the implementation of small size of water-saving technology among dryland areas usually involves less investment and better efficient results as well as more suitable for small farmers to take part in both in terms of their motivation and variability.

Thus, water-saving dryland agriculture is one of the major agricultural development strategies emphasized by the central government, and implemented mainly through MOA, among the other two strategies: variation development and utilization of bare mountain area. In the recent years, many high ranking central government and party leaders such as Chairman Jiang, Premier Zhu and Vice Premier Wen who is in charge of agriculture all visited some provinces in dryland area and talked about the importance of dryland agriculture there.

To improve dryland area's ecological and economic environments, several methods are used. For the land with more than 25 degrees of slope, the soil and water erosion is relatively serious, especially if land is used for agricultural production. For such areas, it is asked to change from growing crops to either grass or trees. Moreover, for those with slopes of 15 to 25 degrees, it is encouraged to change them from sloping land to terrace. These methods are believed to be useful to control soil and water erosion. The

agricultural as well as rural production structure in dryland area will be adjusted. Many water saving techniques with less investment and suitable for the farmers' economic abilities are encouraged. These include furrow drilling, small scale of water cisterns, traditional and modern mulching and coating techniques, fertilization, deep tillage, and seed replacement with high draught-resistant variations and farming system reform.

In order to help the development of dryland agriculture, the central government increased its investment in this area. In 1998, the central government allocated an additional one billion fiscal funding in this field through mainly interest subsidy on the bank loan. In 1999, another 0.5 billion is allocated. But before this year, most of water saving investment funds were managed and allocated by the MOWR. In this year, half of the central government fiscal funding for irrigation (about 0.25 billion) is managed and allocated by the MOA and is mainly allocated for technology related to the dryland agriculture.

In resent years, among the ten agricultural technology development and promotion projects of the MOA, the dryland agriculture is ranked at an important position. For example, starting from 1996, the MOA is working on the establishment of demonstrated experimental fields to develop water saving farming system in dryland area. However, the funding that MOA can allocate to this work is relatively small, about 20 million per year. These techniques include the development of draught-resistant varieties, the water conservation plowing technology, the combination of the use of organic and special fertilizer, and the improvement of soil moisture storage. Meanwhile, some traditional water saving and water storage techniques are encouraged, such as cistern and the drip irrigation.

It is believed that demonstration is an efficient method to introduce water saving technology among rural households that are major agricultural production units with small scale of cultivated land. The MOWR and MOA both have their experimental fields to demonstrate the water saving technology. In the meantime, the special producer's association for cash crops or orchard also play some roles in introducing this technology. As MOA is in charge of agriculture and is closer to rural households, it focuses on the expansion of small and traditional water saving technology. The capital intensive and large-scale technology is only suitable for large farms and in suburban areas where land may not be contracted to each individual household. As most dryland areas are located in the relatively poor and remote area where the education level and household income level are low. Thus, the advanced technology is not suitable for farmers there. In stead, some small and traditional methods are more welcomed by farmers.

Within MOA, each bureau is asked to support and implement government's strategy for water saving agriculture. The Bureau of Agricultural Mechanization that is in charge of extension and management of agriculturally related machinery funded a project in 1996 to develop movable water saving irrigation equipment. Some equipment that is suitable for spring sowing in North China plain is developed. As the sowing season in North China plain is very dry, this equipment can be combined with sowing machine to drip water when seeds are planted. Such machine cost about 3,000-4,000 RMB and can use

tractor's engine as power. Some similar equipment is also developed. It was found by experiments that yield of corn can rise more than 50 kg per mu. At this stage, this kind of water saving equipment is mainly used in those demonstration fields among 12 provinces in North of China. There are two stages for the project. The first stage has been finished and the second one just started. In the first stage, the Bureau spent 3 million RMB on the project. The first stage of the project is implemented in 12 provinces of North China, each county was chosen from the12 provinces. Then a township as well as a few of households is chosen within the county as demonstration households. The newly developed equipment was given to farmers to use without charge. At the second stage, there are 4 provinces, among the 12, are chosen, and each county from each province. The purpose of the second stage is to further improve the equipment in order to be suitable for commercial use. So far some companies in Northeast and Northwest of China produce the machines. In order to encourage farmers to purchase equipment, some time there is additional interest subsidy on their bank loan.

Soil and Water Conservation

China's government in recent years has further realized the importance of reducing soil and water erosion, especially after the large flood of Chang River in 1998. The management of implementation of government's policy regarding to soil and water conservation is part of MOWR's responsibility. Within MOWR there is a Soil and Water Conservative Bureau which is in charge of this work.

The water and soil erosion is quite serious in Northwest and Southwest of China. In the Northwest, the most eroded area is the Loess Plateau. The water and soil erosion area in the Loess Plateau accounted for 430,000 square km. There are more than 1.6 billion tons of soil which flows into Yellow River. Such soil erosion increases the flood threat of the Yellow, as the river is above ground in many places along the lower reach, the highest place is about 10 meters above. In the Southwest of China, the water and soil erosion causes environment deterioration and directly threatens people's life there.

The water and soil erosion areas are estimated at 3.67 million square km, of which, water erosion accounted for 1.8 million. About 2.1 million square km is identified as treatable erosion areas that are further divided into four regions: the upper-reachs of the Chang river, upper and middle-reachs of the Yellow River, the wind erosion area, and the pastureland deterioration area.

In 1991, a law regarding to water and soil conservation was issued, based on a series regulations issued in 1980s. The treated erosion areas are about 30,000 square km per year in 1990s, where the number was 15,000 per year in 1980s. The treatment of small river basin is encouraged by the government and is mainly done by farmers. There are more than 20,000 small river basins are under treatment, among which, 5,000 have reached the treatment standard made by the government.

The government funding in water and soil conservation increased in 1990s. For example, the central government's investment in water and soil conservation mounted 1.6 billion

RMB in 1996, including government fiscal funds, the World Bank, and Asian Development Bank's loans. In the meantime, the national water and soil erosion monitoring system was also established at the national level and the similar system is going to be established at each individual provincial level. The central government's goal is to bring an additional 650,000 square km of eroded areas under control by 2010, and all treatable eroded areas can be basically under control in the next century. However, the measures to realize this aggressive goal are not clear.

Farmers are major supply of labor in most water and soil conservative projects. The central government requires that each rural laborer spend 15 to 20 labor-days voluntarily on the rural conservation projects each year. Thus, 60 percent of total costs of a project are farmers' labor costs. Given that most water and soil erosion areas are poor areas too, the government is considering an increase in financial support in these areas and to lessen farmers' burden of water and soil conservative projects.

Various methods are used in water and soil conservative projects. As we mentioned above, according to the Water and Soil Conservative Law, the land with more than 25 degrees of slope cannot be used as farmland for any crop cultivation. Land with slopes between 15 to 25 degrees, the farmland has to shift from sloping farming to terrace. The land that is asked to shift from sloping farming to terrace is that already under farming, which implies that the re-distribution of such land may be needed. Many areas of land with more than 25 degree of slop are bare. For such land, the government encourages a new contract system. According to this system, farmers are allowed to contract a piece of bare land in mountain or hill areas to grow trees or grass and receive any revenue from the contracted land. The term of the contract for the land use rights is about 30 to 50 years.

The policy seems to be favorable to farmers and has been implemented rapidly in many mountain areas most of which are relatively poor. For example, in Ji County of Tianjin, we were told that all bare mountain areas that are close to the village have already been contracted out. Some farmers even started to contract those remote areas and move into the mountain area to invest on the contracted land. Most contracted land is used to grow fruit trees and can generate income to contractors in three to five years. Under such contract system, farmers take care of the trees carefully and the dead tree ratio falls significantly, compared with those planted by a collective team. In MOWR, we were also told that the contractor of such bare land, especially for the remote areas, can be a farmer outside the village that owns the land collectively, or non-rural households from urban or foreigners. For the initial investment such as purchasing baby trees or build a water reserving facility, the contractor farmers can obtain some bank loan with government subsidy on interests. However, since to apply such loan needs time, some farmers even borrow from the bank without subsidy to start the investment as early as possible.

The bare land contracting system also stimulates water conservation and irrigation in mountain areas. New fruit tree seedlings need water, the commonly used method is to build a cistern to stock water from rainfall. This traditional water reserving method used

to be for small amount of water use, such as pesticide mixed with water and sprinkling through a portable machine in mountain area. With the bare area contracted by each individual household increase, the size of a cistern increases too. The stored water in the cistern becomes a major source of irrigation in mountain area, while the sprinkling and drip technology allows water be used more efficiently and hence is more often used in mountain area.

Conflicts over Water Use

The conflicts of water use among different regions in a same basin are quite common. There are seven river basin commissions to manage the seven largest river basins, each of which involves several provinces. The allocation of main stream river water among the provinces within a basin is done by the commission, according to the basin resource development plan. There is not explicit water use rights in most river basins except for Yellow River basin. When the runoff volume of a river is below the normal year, the conflict among the regions, especially between lower and up reaches due to water use becomes serious. In most cases, such conflicts are settled through the negotiation among the provincial governments. If the conflict cannot be solved at the regional level, the central government has to be involved sometime. When seasonal or temporal water shortage happens, the priority for water allocation by each level of government is urban dweller use, urban industrial use and the last one is irrigation use. In most cases, agriculture would not get enough water and farmers have to temporally shift from irrigated to dryland farming.

The distribution of Yellow River basin's water was done by the central government among the nine provinces that Yellow River passes through. The first Yellow River water use right allocation was in 1986, and was based on a normal year's water amount and historical use of each province. Now, the water allocation plan has to be made year by year even month by month and is done by the Yellow River Basin Committee.

Field trips

<u>Xu Xin Zhuang township, Tong County, Beijing</u>

There are 300 water-saving pilot counties in China under the management of MOWR. Xu Xin Zhuang is one of them and is mainly for the purpose to demonstrate the sprinkling and drip technology. The water source for irrigation is mainly dependent on underground water, which is quite common in North China area. Xu Xin Zhuang is a township (now is called town, which is equivalent to a township) lies in the northern part of Tong County, Beijing. There are 8 villages in the town, 8,550 households, 24,829 of population of which 10,228 is labor population. The area of the town is 59,800 mu. The cultivated land area is 3,440 hectares, of which 2,733 are for grain crops.

The town did not implement the household responsible system that is a dominant production system in most places of China. Hence, the town looks like a collectively owned farm. As the 2,733 hectares of grain growing land was not contracted to each

household, it is quite easy to use the sprinkler technology that is often used on the large size of farmland. There are about 2,480 hectares which are irrigated by sprinklers, accounting for 91 percent of total grain area. Moreover, there are 16.7 hectares of vegetable fields. 20 greenhouses are built on the vegetable area in 1999, and the drip and leaky-pipe systems are going to be used in the greenhouses. The greenhouse was mainly financed by the village itself (about one million RMB) while the installation of the drip facilities are financed by the municipal government of Beijing, through its Water Resource Bureau (about half million RMB). The management of the greenhouse is through contract with each individual household, while the market of the vegetable is for some large hotels in Beijing. Hence, all varieties of the vegetables that are going to be raised are those with high value and hence can generate high returns to the farmers.

There are some questions in our mind when we visited this town. First of all, with its location close to Beijing, the town is a much more developed township that cannot represent the majority of China's rural area. A new technology that can be adopted by such a township can hardly be extend and become a common practice among the masses of China's farmers. For example, the sprinkler equipment is used for the land of which each field has an area of 10 hectares. This large scale of land can only be found in a state-owned or collectively owned farms, while an average household farmer cannot dream of using it. Second, the market access condition for growing high value vegetable already existed in the town before the adoption of drip technology. With a high value added crop, an advanced water-saving technology is feasible, while it is too expensive to be used for most common farmers who have no such a market access condition. Third, the opportunity cost of water used in irrigation was not taken into account when the water-saving technology was adopted in this township. We were surprised to find that for such a rich township with its location so close to Beijing, the grain areas still accounts for 80 percent of total cultivated land. It is not hard to imagine that if the central government's agricultural policy had allowed a place that is close to a large city, such as Xu Xin Zhuang, to freely make its own production decision, grain may not be produced there at all or the area might be reduced considerably. Under the current agricultural policy, grain production is placed as a priority, more water has been actually used in terms of per unit of land or per unit land's value added. The water-saving equipment may save water technically, but not from an economic point of view.

He Xi Wu Township, Wu Qing County, Tianjin

Wu Qing County is located between Beijing and Tianjin. Two major highways and a railroad pass through the county and hence the transportation is quite convenient. The area of the county is 1574 square km and cultivated land is 91,000 hectares. Demand for water calculated from domestic need and crop's requirement is about 520 million cubic meters, of which 400 million is for agriculture. The real consumption of water is 250 million cubic meters, of which ground and surface water accounts for, respectively, 90 and 160 million. While surface water is all for agriculture, about half of underground water is for agriculture too. The water-saving irrigation area is about 28,670 hectares and is planned to expand to 58,000 hectares in next ten years. The water storage is mainly

dependent on the utilization of riverbeds and deep ditches, and reserved water mainly come from rainfall in summer when about 80 percent of annual rainfall occurs.

He Xi Wu Township is located exactly halfway between Beijing and Tianjin and has an area of 38.4 square km. The east border of the township is the Grand Canal and a wastewater canal from Beijing passes through the west border of the township. The cultivated land accounts for 2,600 hectares, of which grain area is about 1,860 hectares and vegetable area 800 hectares. The township is a major grain and vegetable production area in the county. In 1998, the grain output as 22,000 tons and vegetable 80,000 tons. The gross value of agriculture is 76 million RMB. The annual income per capita is about 3,700 RMB, which is similar to the rural incomes in the rest of the county but is much higher than the average level of the country (around 2,000 RMB).

The middle and east parts of the township depend mainly on underground water for irrigation, as these areas are identified to be suitable for wells. There is no salt-water aquifer and hence fresh ground water resource is quite rich. In the west area of the township, the shallow ground water has some salts and the cost of deep well is too high for agriculture, as deep aquifer of ground water is more than 150 meter deep. Such in the west area agriculture is typical dryland farming and depends mainly on rainfall. The wastewater from Beijing is also used for irrigation. The leader from the town believes that the standard of the treated waste water has reached to the standard for irrigation water, which is not consistent with what we heard from the Bureau of Tianjin Water Resource, where we are told the treated waste water is still quite polluted.

The township is rich in underground water and hence is one of the well irrigation areas in the county. During 1991 to 1998, a 1,733 hectare water-saving well irrigation project has been developed, with 370 wells, each irrigates about 4.67 hectares. The anti-leakage channels accounts for 133.255 km, of which low pressure underground plastic pipelines are 119.275 km. The total investment of the project accounted for 3.75million RMB, 2150 RMB per hectare. The government financial support for the project accounted for 25 percent, including funding from Tianjin government and central government which is also through the municipal level's government. The local government, including county and town invested about 25 percent, while the rest of half is from farmers. The project generates significant economic results in terms of water savings. Compared with the situation before the project, more than 2.6 tons of water is saved each year, implying water is saved by 33%. Moreover, about 122,400 Kw of electricity was saved, accounting for 12.75% of total use. 21.9 hectares of arable land was saved due to the reduction of land occupied by open ditches, accounting for 1.5% of cultivated land. Water-saving irrigation also saves labor, about 26,000 days can be saved, accounting for 33% of total labor use in crop production. These result in grain production increasing by 1.26 million kg, with growth rate of 8.8%, vegetable increasing 4.08 million kg, 16% growth rate. Thus, value added of crop products increases by 1.44 million RMB per year and 825 RMB per hectare.

The domestic use of water by rural population is also improved. The township includes 32 villages, with a permanent population of 25,000 and mobile population 4,500. The

comprehensive domestic water supply project was started in 1991. Through five stages during the five years, the running water can supply almost the whole township by the end of 1996. The rural domestic water supply project is a key demonstrative project in Tianjin. 6 water supply stations are built, with water supply of 5400 cubic meters per day. The total investment accounted for 3.33 million RMB. The Water Management Station manages the water supply project at the township. The station is also in charge of water fee collection.

At the village level, there is self-managed water management group that selects one villager to be in charge of the management work of the well. When a farmer wants to use water to irrigate his land, he contacts this person. The water used for drinking and irrigation is metered and user pays the operational costs (mainly electricity costs). The plan for well construction and location is made jointly be the township and county, i.e., farmers cannot dig a well by themselves.

The Team visited farmland that grows corn in the township. Underground pipes connect the well to the fields. The distance between the outreaches is 25 meter. When farmers need to irrigate, a plastic pipeline is put on the outreach and water will flow into field. However, there is no distribution pipeline in the field, i.e., once water reaches field, the irrigation method is still surface flooding. The double cropping is prevailed, i.e., the spring wheat follows by the late corn. The area of the farmland is quite large, while each individual household contract one small piece of it. It is hard to tell the contract border for each household, except in the harvest season, it can be seen as some households harvest early and some later. The irrigation of the field is according to each household's request, which allows the water fee charged on each household.

<u>Shui Gao Zhuang Village, Xin Ko Town, Xin Qing County, Tianjin</u>

The Xin Ko Town is a major vegetable production area, like most of townships in Xin Qing County, the suburb of Tianjin. Vegetables are mainly supplied to urban area of Tianjin, while merchants from other regions such as Northeast of China often come to purchase products. Among the 3,647 hectares of cultivated land, there are more than 2,670 hectares of vegetable land, while grain areas, mainly for wheat and corn are about 1,000 hectares. The town includes 18 villages with population of 35,000. The town is a quite developed area with annual GDP around 125 million RMB in 1998. The non-agriculture accounted for more than two-third of the GDP, and annual income per capita is 4,380 RMB in 1998, two times the national average level.

The area is a water shortage area with annual rainfall of 540 mm. Most of rainfall occurs during July to September, while spring and early of summer are quite dry. Similar to He Xi Wu town, the water saving irrigation focuses on the improvement of ditches. About 120 km of canals are lined. These ditches become the major water storage facility with total water reservation capacity being 1.5 million cubic meters during rainfall season. With such water storage, together with water stocked by riverbeds, the water shortage during spring can be lessened if the rainfall is enough during summer and fall. However,

the water-saving irrigation equipment has just been introduced and sprinklers will be used for 267 hectares of vegetable fields in Shui Gao Zhuang village.

The underground water condition is good as shallow water aquifer has enough water and can be easily recharged during rainfall season. Such to develop the further use of underground water is encouraged by the government, according to the understanding of the county's chief. During 1998/99, 350 new wells were dug and each well can irrigate about 2 hectares of farmland. Each well costs about 5,000 RMB, including the installation of pump. The well is drilled according to the plan made by the village and township Water Management Station, after geographical survey for the resource situation of the ground water.

At the village level, there is agricultural service team, which is also in charge of water management. The water use fee, mainly the electricity fee is included in the land contract fee. Moreover, they do not measure and control of volume of the water used by each individual farmer. The land use contract fee is paid by the household to the village and usually is about 1200 to 1800 RMB per hectare. Then, the special team of the village is in charge to provide water and other services. It is obvious that this method does not encourage farmers to save water, as the use of water does not affect the amount of the land use contract fee.

While well water for irrigation is from the shallow aquifer of ground water, industrial and domestic use depend on deep wells. According the county chief, use of the deep aquifer underground water is under the strict control, i.e., to dig a deep underground water well has to get approval from the Bureau of Tianjin Water Resource, the government agency at the municipal level to in charge of water resource management. Moreover, for the underground water used by industry, there is underground water resource fee charged by the Bureau of Water Resource, besides the operational costs of the well.

As township industry is quite developed, the water pollution by industry is quite serious. The township government has started to realize this problem and is going to adopt some control measures. It is not clear what kind of measure is going to be used. We were told that if an enterprise cannot reach the pollution control standard in its wasted water, it has to stop its production. But the implementation of such regulation is questionable given the current technical condition of most township enterprises.

The Shui Gao Zhuang village is located at the northwest area of Xi Qing County, with population of 4300. The size of the village is quite large, compared with most villages in the North China. Strictly speaking, the village is more alike a small society of which there are all kinds of economic and social activities. The corporation named by the village seems to be in charge of most economic and social activities. There are 13 enterprises under the corporation, with 2,300 employee, accounting more than 70 percent of labor population in the village. The products of the township enterprises include textile, processed food, chemical, plastic and steel products. The total assets of the industrial enterprise amount to 300 million RMB, and the profits and tax income accounted for more than 50 million in 1997 and 1998. The salary of the village enterprise

employee is quite high, above 10,000 RMB per year in average. The per capita income of the village is more than 6,000 RMB per year, two times higher than the national average level.

There are 800 hectares of cultivated land in the village, of which 267 hectares are vegetable land and 66.7 hectares are orchard. Two farms that are the two of the 13 enterprises under the corporation operate the 467 hectares of grain land. The entire farming process for grain production is mechanized and hence there are only 103 employees in these two farms. All grain land is used for growing wheat, while soybean may be planted after winter wheat. However, when we visited the village, there is only one-fourth of the grain land that has soybean in the field. The majority of the grain land is empty and is prepared for the winter wheat. Thus, it seems that crop rotation is implemented in the village, which is unusual in the North China where land is scare and often used for double-cropping.

Investment in the agriculture, especially in grain production is subsidized by the income from the village industry. For example, the purchase large scale farming equipment and the construction of farmland and agricultural hydrological projects are all financed by the village, using income earn from industrial enterprises. All roads in the fields have been reconstructed and are in a good condition, and all ditches are connected. There are about 34.6 km of lined ditches, 9 pumping stations. The water storage capacity is about 500,000 cubic meters. By their estimate there is a gap of 500,000 cubic meters between supply and demand.

The vegetable land is contracted to farmers. There are 30 percent of village households who work in the vegetable production and each household has more than 10 mu of vegetable land. Most of vegetable land will become greenhouse during fall and winter. Irrigation of vegetable and grain land is subsidized by the village and households who contract vegetable land only need to invest on plastic pipe and small pump to delivery water from ditch to the land.

Irrigation water is mainly transferred from the river passing through the village. The village built a pumping station at the river and then river water is further pumped to canal, i.e., there are two levels of bumping stations and there is no water reservation facility such as a small reservoirs or pond. The village pays the water fee to the county's Water Management Bureau at 8 cents RMB per cubic meter. There is no actual monitoring system for the Bureau and hence the charge mainly depends on the capacity of the pumps installed by the village.

GROUNDWATER RESOURCES
IN THE
HAI BASIN-NORTH CHINA PLAIN
AND
SHAANXI PROVINCE

Hai Basin-North China Plain

The Hai Basin is delineated by the area between the Songliao Plain in northeast China and the Yellow River Basin to the south and west. (Figure one). The basin contains the Hai and Luan river systems, all of Beijing and Tianjin municipalities, Hebei Province and portions of Shandong, Shanxi and Henan. About 60 % of the basin is mountainous and 40 % is plains. The basin covers an area of 318,151 square kilometers. The cultivated area in 1980 equaled 11.2 million hectares, of which about half was effectively irrigated. The mean annual precipitation is 560 mm with a range of 200 to 2000 mm. Eighty percent of the precipitation falls from June to September. The total net water available in the Hai Basin is 41.9 billion cubic meters (bm^3), estimated by adding 26.4 bm^3 of surface water to 27.5 bm^3 of ground water with 12 bm^3 double counted because of reuse. Actual use was about 39 bm^3, of which, 43% (15 bm^3) was from surface water sources and 22 bm^3 (57%) was from ground water sources. Agricultural consumption equaled 27.1 bm^3, or 68% of the total basin use. Sixteen bm^3 or 60% was derived from groundwater sources. Each person in the basin had an average of 430 cubic meters of water available each year making it one of the driest regions of China. Every forty years, a major drought hits the region. Small droughts occur on a frequency of every five years. (11)(12)

Institutional Setting

The drilling of wells in China is performed by private well drillers. In most areas, wells are permitted with restrictions on lateral spacing in relation to other producing wells, and well depth. A license is required to contract with a registered well driller to drill the well. Once a well is completed, another license is required to use water from the well. To drill a well into the shallow aquifer for agricultural purposes at 100 meter depth may cost 30,000 RMB ($3,750 US). The government may provide support by paying 5,000 RMB or about 17%. The Ministry of Agriculture administers the well permitting program; however, deep wells of 300 meters deep are under the jurisdiction of the Ministry of Natural Resources (2).

Monitoring of ground water quality is under the jurisdiction of the Ministry of Water Resources, Department of Hydrology (2). Monitoring of groundwater levels is conducted by the Ministry of Water Resources, Department of Hydrology. Many years of data exist on individual wells in various areas.

However, due to short well life from overdraft induced depletion, poor well construction techniques and water quality degradation, insufficient data exist to construct long term well hydrographs (1).

There is no uniformity in the cost of ground water. Commonly, irrigation water costs about 7 to 8 cents per cubic meter and is set by the provincial government. The highest price is about 20 cents per cubic meter for a use such as fisheries (100 cents equals one RMB, 8 RMB equals one US Dollar, 1999 exchange). In some areas, such as the northwest loess region of China, electric pumps are used and set at 200 to 300 meters deep. Since the energy required is significant and energy purchasing capacity of the farmer is low, the government provides a subsidy by charging only a fraction of the cost of electricity. The actual cost may be 10 cents per kilowatt hour but the farmer is only charged 2 cents per kilowatt hour. However, if a high value crop is grown, less subsidy is provided (2).

Aquifers and Lithology

The Hai Basin has a variety of geological settings that control and/or influence ground water storage, availability and quality. In the mountainous regions, consolidated formations containing water are referred to as "cranny" aquifers. Ground water storage is contained in cracks in hard rock due to secondary porosity. "Hole" aquifers; refer to the Pliestocene, unconsolidated lenses of clay, silt, sand and gravel units of the alluvial flood plains. (8)

Ground water in the North China Plain is in lensed formations up to 300 meters deep, generally from alluvial fans deposited from rivers exiting the mountains in the western part of the Hai Basin. In the plain of the Hebei Province and elsewhere in the basin, repeated inundations and silting by rivers laid down lenses of gravel, sand, silts and clays. These lenses are interfingered and resulted in complicated subsurface geology. The rivers often breached their banks and changed channels. The lenses of material are typical of stream geomorphology with sandy point bars and clayey floodplains. The size and sorting of the deposited particles was determined by the stream carrying capacity based on velocity. Abandoned gravel bottom ancient channels still carry ground water today and provide excellent storage. Most deposition occurred during the Pliestocene time period. Typically, the bottom of these deposits ranges from 30 to 50 meters below land surface. Sand lenses tend to be 10 to 30 meters thick. The specific yield of the shallow aquifer was reported to be 10% to 20%. The uppermost layer at land surface tends to contain more fine materials and has a specific yield of 5 to 10%. The best aquifer storage occurs in the alluvial fans, which tend to be composed of coarser materials, followed by the river channel belts, deltas and floodplains (1)(7).

Recharge varies considerably depending on the size of the materials on the surface. In some areas little percolation of precipitation occurs. Some of the ancient river courses are still hydraulically connected to the surface and allow for rapid percolation of rainfall. The common rates of recharge for surface materials in the basin are medium sand-12 to 18 m/day, fine sand-6 to 10 m/day, and silt-4 to 6 m/day (7).

The shallow ground water has been estimated to be of young age and recharged on a renewable cycle of every 8 to 10 years. Deep aquifer water through Carbon 14 dating has been determined to be thousands of years old and explains the large cones of depression in the North China Plain (6).

Water Use

Shallow ground water is a commonly used term, usually referring to saturated lensed materials at 100 meters of depth or less, unconfined, of relatively poor quality and used predominately by agriculture. Deeper sand units are generally of better quality and are used by industry and public water supplies. In Beijing, about 60% of the total water use of 4.2 billion cubic meters/year is used by agriculture and 40% by industry and municipal use (4).

The total water usage for the five large river basins in China (Hai, Yellow, Huaihe, Song and Liao Rivers) was 247.8 bm^3 in 1996, of which 83.3 bm^3 was from ground water aquifers accounting for 34% of the total. For the Hai and Luanhe River Basins, 58% of the total water supply is from ground water aquifers. Ground water accounts for as much as 63% of total water use in Beijing, and 71% in Hebei Province (8).

There are 3.3 million irrigation wells in the North China Plain and the irrigated acreage is 13.3 million hectares accounting for 25% of the total irrigated acreage in China. The total amount of ground water utilization for irrigation increased from 48.1 bm^3 in 1977 to 64.1 in 1993 accounting for 16.4% of the total irrigation water use of 391 bm^3 (8).

Well density on the Hebei Plain averages one per 7 to 8 hectares with an average yield of 20 to 50 m^3/hour (7).

In Tianjian in 1995, a total of 1.2 bm^3 of water was used by agriculture in the area. About 60% was derived from surface water sources and 40% from ground water. Ground water is used primarily to supplement surface water supplies or used on high value crops. The ground water reserves or storage was reported to be .6 bm^3 to .8 bm^3 on any given year. (11)

Groundwater Problems

The water resources of China have been exploited by industry and urban areas, which has diminished the supply for agricultural uses. The agricultural area that is water short is about 16 million mu (1 hectare equals 15 mu) and the shortage amounts to 1,600,000,000 cubic meters. While growth and economic development is needed, over half of the total farmed cropland could increase yields with irrigation. The competition for water resources has resulted in many ground water problems (6).

In the Piedmont Plains in the western and northern portion of the North China Plain, water demand has doubled since 1970 due to urbanization, industrialization and

expansion of irrigated farmland. For example, Shijiazhuang City District located in the piedmont plain of the Taihang Mountains produces grain with 537 millimeters of precipitation. Grain output in the late 1980,s reached 12,000 kilograms per hectare with water consumption of 850 millimeters per year. The precipitation deficit was withdrawn from ground water sources and averaged 80 to 100 millimeters per year. More water was being withdrawn from the aquifer than was being recharged and the water table began to decline. In the 1980's water table declines amounted to .8 meters per year, but has increased to 1.0-1.2 meters per year in the 1990's (6).

At Luangcheng Station of Agro-ecological Systems, Chinese Ecological Research Network, Chinese Academy of Sciences, the water table has shown an increase in the rate of decline. In the 1950,s the depth to water below land surface equaled three to four meters. The depth to water increased to 20 meters in the 1980's and about 30 meters in the 1990's (6).

An assessment was conducted in 1986 on the ground water resources of China, which resulted in the total estimated ground water storage of 871.6 bm^3. Approximately 33% of this total was in the northern portion of China and 67 % in the south. The same inventory procedure was repeated in 1997 and resulted in a quantified storage of 694.2 bm^3. The ratio of resources north and south had changed slightly with 30 % in the north and 70 % in the south. The change in groundwater storage over the eleven year period amounted to 177.4 bm^3 (20.3%) or an overdraft rate of 16.1 bm^3 per year. One reason for the decline, in addition to increased withdrawals, was a reduction of precipitation. In 1986, precipitation equaled 643 mm, but was down to 613 mm in 1997, a 4.6 % reduction. The overdraft of aquifers for North China Plain has been estimated at 74 bm^3 (per year) which accounts for 86% of the total overdraft in all of China (1)

In the shallow ground water aquifer, the overdraft rate is quite variable. For example, in the Song Liao River Basin, the annual overdraft rate exceeding recharge was less than 30% in 1986 but increased to 42.5% by 1997. Similar increases occurred in the Hai Basin where the rate increased from 70 % to 95.7%. The lower Yellow River increased from 30% to 31% and the Huai River Plain (No. China) more than doubled from 15% to 33.9 %. In the vicinity of Tianjian, the rate of overdraft has exceeded recharge by 150%, caused predominately by large withdrawals for irrigated agriculture. In general, the largest declines in the potentiometric surface occurred in the western portion of the Hai Basin in a north-south zone adjacent to the mountains. Small declines tended to occur in a north-south zone along the coastal areas. (1)(See Figures 2&3)

In the plain of the Hebei Province in 1964 a large portion of the basin had depth to ground water of less than one meter below land surface. By 1984, some local areas in the basin had ground water at 24 meters below land surface. In 1993, more dramatic change occurred in several large areas with a depth to ground water greater than 30 meters. One well hydrograph demonstrated the significance of the change from two meters to water below land surface in 1964 to 20 meters in 1984 and 37 meters in 1993. The bottom of the shallow aquifer in this area is marked by a confining unit at about 50 meters which means that about 13 meters of saturated thickness remains in the aquifer or about one

fourth. With only 13 meters remaining, the reliability of wells will be doubtful due to the length of well screen, position of the screen in the bottom of the aquifer and the pumping drawdown in the well, (total dynamic head). Wells in this location and situation would be likely to surge and be unproductive and at least, unreliable. In the Chaozhou Prefecture of Hebei Province the water table is 80 meters below sea level. (1)

In the Hielonggang River basin, a shortage of surface water resources, has caused serious depletion problems in the deep aquifer. Wells penetrating the deep aquifer were completed in the 1970,s. The deep aquifer has declined 2 to 3 meters per year since development began. Since the 1980,s the shallow aquifer has also been depleted (6).

The water table has declined in the vicinities of the larger cities of the North China Plain. The overdraft rate has resulted in large dewatered areas or cones of depressions in these areas. The deepest cone is located underneath Boading City at 53.16 meters below land surface, followed by Tangshan City at 48.6 meters. The cone under Beijing is about 40 meters below land surface and the mining area near Tangshan is currently at 26.85 meters deep. Another revealing characteristic of a cone of depression is the lateral extent, which is a function of the recharge area, withdrawals and aquifer conductivity. The largest area contained within a cone of depression is located under Beijing covering 1000 km^2. This is followed by the cone (sometimes referred to as funnels) under Boading City at 283 km^2, Tangshan City at 282.5 km^2 and the Tangshan mining area at 202.5 . The criteria or potentiometric contour for the base line is unknown for the analysis but is believed to be consistent. In total, there are 61 cones of depression located in 21 provinces with 21 of those located in the better quality deeper aquifers. The total estimated area is greater than 80,000 km^2 and concentrated in the North China Plain. (1)

Aquifer storage on the western side of the North China Plain has been estimated to be depleted by the year 2030 using linear regression based on the rate of decline from 1980 to 1996. Depletion of the aquifer will not be linear; however, it gives an indication of the approximate longevity for dependable ground water supplies in the region. In reality, the rate of depletion will lessen over time as withdrawals decline due to unreliable supply and recharge increases with gradient. The annual overdraft ranges from 105% to as high as 143% of the average available quantity for the plain in the Hai and Luan River Basins (6)(8). Other experts have estimated the year of depletion to occur in many areas by 2015 and a concurrent shift to dryland farming. (9).

The environmental impacts from ground water overdraft include degradation of water quality, land subsidence (up to 2 meters in some locations) and saltwater intrusion into portions of aquifers that were previously fresh, mainly near coastal areas. The most serious saltwater intrusion is occurring in Laizhou Bay where an area of 10,000 km^2 is affected. Cities along the Bay include Dalian, Qin Huang Dao, and Cangzhou. Some impacts have also been documented in the cities along Bohai Bay (1).

Land subsidence is greatest in Tianjian at about two meters and in Cargzhou at greater than one meter (1). Subsidence at the Asia Beijing Hotel, in which we stayed, was reported at one meter (10). It was reported by the Tianjian Conservancy Commission that

overdraft of the aquifers and the harmful consequences had stopped and withdrawals by agriculture were being restricted to the safe yield of the aquifer through the use of permits. If overdraft was still occurring, it was because of heavy industrial withdrawals. From 1970 to 1980, the water table dropped but is now stable. The average annual groundwater availability was 700 million m^3 per year. Each year, only 650 to 700 million m^3 are withdrawn by wells. In the Tianjian area, there are 28,000 pumping wells. Eighty percent of the water is withdrawn from ground water sources, 11 % for domestic use and 8% for rural use outside the city. Water levels have been monitored since 1980. In the northern portion of the province, the water table was within 2 meters of land surface, in the southern part, the water level was 80 meters below land surface. They are currently monitoring 408 wells with water levels measured every 5 days for the past 10 years with recorders on about 100. (12)

One field trip was made to Wuqing County, just outside Tianjian. The county has 1,574 km^2. The total potential water demand is .52 bm^3 for all uses. About .16 bm^3 is available from surface water sources and .09 bm^3 from ground water aquifers. With .25 bm^3 available and .52 bm^3 potential use, Wuqing is a water deficit county. Current water use for agricultural purposes equals .21 bm^3 per year with about 25% coming from ground water sources. There are 373 wells in one irrigation district in the county; 184-shallow, 174-mid level and 15 deep wells. Recharge to the county is primarily on the western border with flow being west to east. In the middle and eastern part of the county, all three aquifer levels contain fresh water. In the western part of the county, the shallow and middle aquifers are salty and only the deep aquifer is fresh. Shallow, middle and deep aquifers in this county refers to; shallow-less than 50 meters, middle-100 to 150 meters and deep is greater than 150 meters below land surface. The deposits are mainly clay, but several sand units serve as aquifers. The first sand unit is between 30 and 50 meters below land surface. Some data showed a falling water table. Ten years ago, the water table was about 4 meters deep, and today is 10 to 11 meters deep. Shallow wells are replaced about every 15 years and deep wells, every 20 years. Each well irrigates approximately 70 mu.

The Xin Kou township, south and west of Tianjian, has a population of 35,000 in 18 villages with 54,700 mu of arable land. The most severe water shortages occur in the spring. Ground water is available in an aquifer from 30 to 60 meters below the surface that contains good quality water. Recharge is naturally occurring from percolating precipitation. In 1998 and 1999, 350 new wells were completed to explore the ground water potential. Each well services about 30 mu. The deep aquifer has limited recharge and strict regulations on its use. Shallow well spacing is made according to a water plan, but sounded like wells (mostly electric) were installed along power lines. Professional well drillers install the wells at a cost of about 5,000 RMB to a depth of 30 to 50 meters.

Some proposed solutions to the overdraft problems are water saving devices and techniques, artificial recharge using stormwater recharge, treated sewage and enhanced water management. Most often mentioned, as solutions were bioengineering advances in dryland farming. The assumption is that overdraft cannot be stopped in the North China

Plain and new varieties of existing crops that require much less water with the same yield will be found (1).

Groundwater quality

Some ground water quality problems are naturally occurring from deposition of sediments into the sea in ancient times. The flushing rate of recharge has been insufficient to render the shallow aquifer fresh. This is especially true in between the old river channels where conductivity of materials is low, recharge is slow and there is little or no vertical percolation. The salt water location and depth is difficult to predict without exploratory well development and with limited vertical percolation in their location, it would be difficult to flush the salt from the formations (7).

Ground water pollution is most serious in eastern China while quantity related problems are concentrated in northern China (3). Near Tianjian, it was reported that high concentrations of Nitrogen was occurring in the shallow aquifer from sewage applications. The middle aquifer between 200 and 300 meters below land surface is naturally salty. Fresh water can be found above and below the middle aquifer at Tianjian. (12)

Salinity problems are most severe in the North China Plain especially on the south side of the Yellow River (3).

Field Trip to Suburbs of Beijing, Tong County Demonstration Project

The Water Team visited a demonstration project near Xu Xin Village on Sept. 15, 1999. The purpose of the project was to demonstrate water saving technologies. We viewed one field in detail where underground pipe was being utilized to bring water to risers for distribution over the field. Water control valves were operated remotely by computer. The total demonstration area was 5,500 mu. (one hectare=15mu). Ground water was being pumped with electric submersibles pushing 7 to 8 meters of total dynamic head. Last year the static water level was reported to be 14 meters below land surface and had risen to 9.5 meters this year. The saturated thickness remaining in the shallow aquifer was reported to be about 15 meters. The average long term water table decline was reported to be 2 meters per year. We also toured 30 green houses used for high value vegetables.

There were 3,440 hectares in the Tong Township that contained the demonstration project. The township contained 587 wells. Forty wells were monitored annually for depth to water and 5 were selected for continuous monitoring. In February of 1998, the average depth to water was 7.21 meters below land surface. In February of 1999, the mean depth to water was 7 meters. It was reported that 78 wells had been replaced over an unknown time period because the water table had dropped below the well screen and age deterioration. The wells were lasting 10 to 15 years and pumping sand near the end of the life. New wells were costing 8,000 RMB (approximately $1000, US) to a depth of 100 meters. It is not understood why the wells were so deep with the water table so high, unless the uppermost aquifer unit was confined and had to punctured with the well at

depth. The well diameter was reported at 30 cm and generally electric. The aquifer used for agriculture was 100 meters deep. Another aquifer was located between 100 and 150 meters and used for drinking water due to the good quality. The city wells were reported to be 700 to 800 meters deep in the Hontreeson aquifer and of good quality. Recharge to the shallow aquifer was accentuated by dams in streams that could percolate one meter of water over some unknown time period.

Ground Water in Shaanxi Province

The total water resources in the province are 44.5 bm^3 with 42.6 bm^3 being reported as surface water, 16.1 bm^3 as ground water with 14.2 being double counted. The reported available ground water (assumed recoverable) was 4.52 bm^3. The total water use in the province was 8.72 bm^3/yr with 4.62 coming from surface water resources and 3.65 from ground water. Most of the ground water was available and used in the central plain of the province. Of the total ground water withdrawals, 2.18 bm^3 was from the shallow aquifers and 1.47 bm^3 was from deep aquifers. The shallow aquifer is connected to the surface and receives recharge from percolating precipitation. In the northern portion of the province, shallow ground water is found at a depth of 2 to 8 meters below land surface. There is little data on the deep aquifer here. In the southern portion of the province, shallow ground water is from 2 to 20 meters below land surface, with little data on deep ground water. In the central portion of the province where most of the ground water use occurs, shallow ground water is found from 8 to 40 meters below land surface. Good quality water is found in the deep aquifer, greater than 200 meters and greater than 1000 meters is hot water.

Ground water problems in the province include overdraft areas east of Xian where the water table has fallen and some local subsidence has occurred. In some of this area, there is no shallow ground water available and many new wells are dry holes. Due to a falling water table, the City of Xian changed to a mix of surface water and ground water in 1996. Since that time the water table in this area has stabilized. The most serious ground water quality problem is an area of excessive Fluoride causing health problems for residents.

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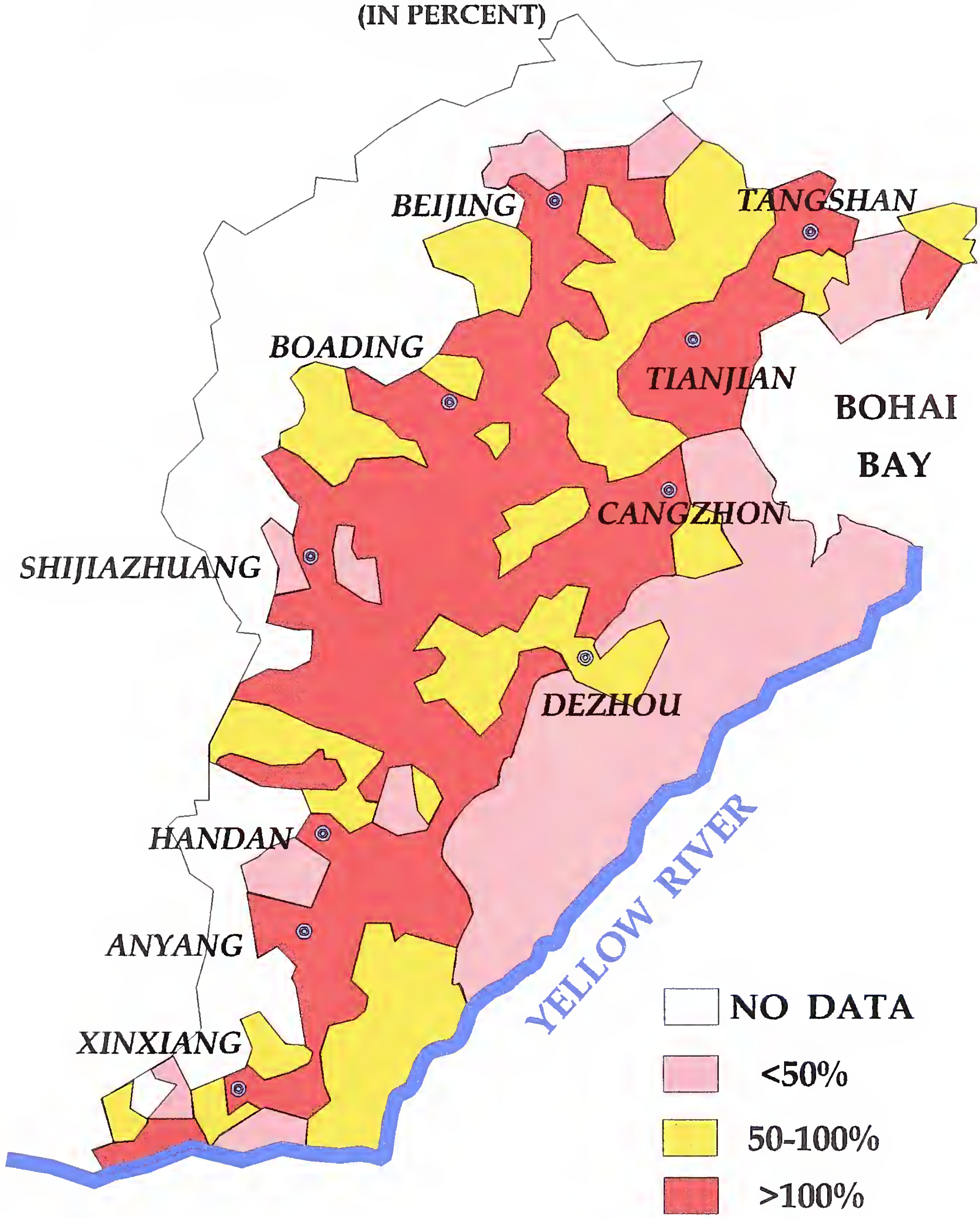
HAI BASIN
PEOPLES REPUBLIC OF CHINA

FIGURE ONE

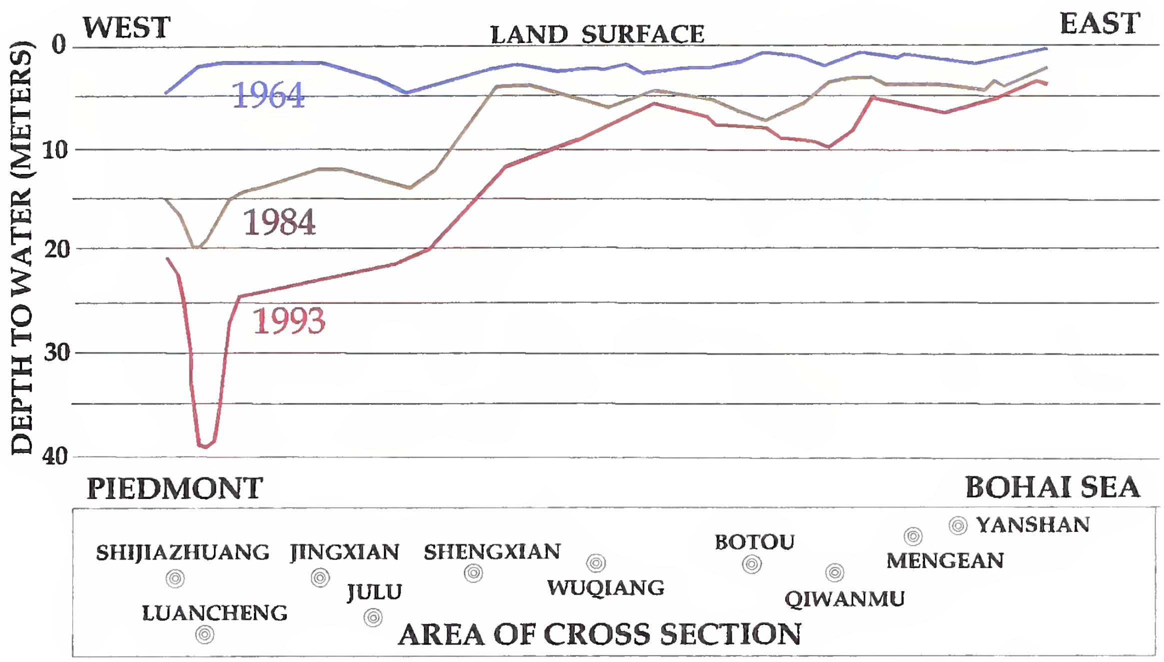
NORTH CHINA PLAIN
GROUND WATER DEPLETION RATE
(IN PERCENT)



SOURCE: CHINESE ACADEMY OF AGRICULTURAL SCIENCES 1999

FIGURE TWO

NORTH CHINA PLAIN
WATER TABLE PROFILE
SELECTED YEARS



SOURCE: CHINESE ACADEMY OF AGRICULTURAL SCIENCES, 1999.

FIGURE THREE

Chapter 5

Management of Water Supplies

Dale Heermann

The demand for water in Northern China exceeds the available supplies. The available water is allocated by the Ministry of Water Resources. Water rights as we know them in the United States are not used for water allocation. They are assigned to the province with the highest priority for the cities and people and, second for the industry and last for agricultural and irrigation. Water is also allocated for environmental requirements. The current allocation provides approximately 70% for agriculture and irrigation. In the Hai Basin, agriculture is getting only 50 % of which 70% comes from ground water. There is a strong concern that the increased demand will reduce the water available for agriculture and the trend will be to convert irrigated area to dry land farming. There is 53 million ha of irrigated land in China.

The Ministry of Water Resources is in control of all the water in China and controls the water for irrigation. The Ministry of Agriculture has practically no input with respect to irrigation except that they may make estimates of crop water requirements. This is obvious at every level whether it be at the State level, province, county or township and village level. Therefore the Agriculture agencies put most of their emphasis on the dryland option and have targeted programs for increasing production on dryland. The funding for irrigation at the state level is only 10% of that for water projects. The funding for dryland agriculture is also very low even though the central government is beginning to recognize the need and value of increasing dryland production.

Irrigation Systems

Surface irrigation systems are used on 97% of the irrigated area. There is a real concern that the irrigation systems must be improved with the ever increasing municipal and industrial water demand. A strong emphasis is being put on water saving irrigation (WSI) systems. This is the buzz word that was used by all the groups visited. They claimed to have upgraded 15 million ha with WSI. TheWSI systems can be classified as follows:

1. Lined canals or installed buried pipe - 8.7 million ha,
2. Installed low pressure irrigation - 5.2 million ha,
3. Installed sprinkler irrigation - 1.2 million ha, and
4. Installed micro irrigation - 0.27 million ha.

The financial capital is quite limited for individual farmers to invest in WSI even if it does increase his efficiency. The government has limited programs for assisting local areas with the upgrading of their irrigation systems. The uncertainty of irrigation water from

year to year can also be a deterrent to investing in WSI. The government will provide subsidies in the event that capital investments are made in WSI and then water is not available. The irrigators in the areas of high lift (Northwest) are provided a reduced rate on electricity for pumping. They often pay 70-80% less per Kwh.

The scale of irrigation size varies from the south where the irrigated farm size is 267 m^2 per person as compared to 6500 m^2 per person in Northwest China. These small scale farms limit mechanization. With rice production only 4% is planted with a planter and only 10% is harvested mechanically. Corn is only mechanically harvested for 2% of the area. Driving through the rural areas, we saw much of the corn being harvested. The stalks are generally cut and the ears with husks are taken to their homes. Ear corn can be seen laying in front of the house as well as some ingenuously hang the ears on the edge of their house roof. We seemed to see ear corn everywhere that we went. They husked the corn at their house. The corn was shelled and sacked. We observed some using small corn shellers while others were shelling the corn by hand. We saw many then take the sacks of corn and put it on the roads in very thin layers for further drying. Most of this is probably fed to their livestock. We rarely saw more than a few head of hogs, goats, beef, and dairy at one location. It would appear that the livestock is quite disbursed and not concentrated in larger herds as in the United States.

Wheat is produced both on dryland and irrigated. There is considerable double cropping where wheat and corn are grown on the same field each year. The mechanization of wheat production is much higher than that for corn and rice. Approximately 67% of the wheat is planted by machine and 60% is harvested mechanically. We noted a number of wheat drills at stores along our trips through the country side. They appeared to be approximately 1.5 to 1.8 m width. Most of the tractors are small (15hp) and when being used in the field are pulling trailers moving almost everything including bricks and rock as well as agricultural products.

<u>Sprinkler Demonstration Site</u>

We visited the Tong County Water Bureau and toured their irrigated area and visited one of the WSI sprinkler installations. The system was irrigating corn on a 10 ha field. The corn did not look as good as I would expect in eastern Colorado. It was not as dark of green as one would expect in a high yielding corn field. The plant population was lower than with most irrigated corn in the US. The field was quite weedy and a good stand of velvet leaf was observed.

A buried mainline had 20 outlets serving laterals with 12 sprinklers on 18 meter spacing. The mainlines were installed on 20 m spacing. The 18 x 20 meter spacing appears to be large for obtaining a high coefficient of uniformity. The system was controlled by a PC via radio. The interesting fact was that the farmer had to move the sprinklers from one set to another by hand. The system was operated on a 7 day frequency with 8 hour sets. There were 20 sets and on Sunday only two sets were needed. The sprinklers were operated at 25 m head. At the field site we were told that the system applied 34.5 mm per irrigation However, based on the numbers from the design figure, the application depth

would approximately double this amount. If they assumed an irrigation efficiency of 50% for the demo system the numbers would reconcile.

Micro Irrigation Demonstration Site

The micro irrigation system was installed for vegetable farming for 30 households. The field had greenhouse structures occupying a 0.064 ha area. The greenhouses had a brick wall on the north side with tubular steel arches for the fastening of plastic sheeting. The greenhouses were spaced leaving another 0.064 ha area between each other. The irrigation network was installed through out the 13 ha area with closely spaced (estimated at 45 mm spacing) drip lines to irrigate in the greenhouse and the open area between the greenhouses. The greenhouses were constructed and the micro irrigation system was being installed. The pipe is being manufactured in China but the drip irrigation tubes are being obtained from Israel.

Low Pressure Irrigation Site

We visited a low pressure irrigation system in Wu Qing county near Tianjin. The area for the township was 38.4 km^2. They had an irrigated area of 2660 ha which includes 800 ha of vegetables and 1860 ha of grain crops. There income per person is 3700 RMB which is well above the country average. The area was irrigated with low pressure WSI (estimated to be 2/3 of the area) and surface irrigation. There were 373 wells pumping water into low pressure buried pipe lines. Each well provided water to 4.7 ha. The well is estimated to be 40 to 60 cm in diameter. An electric submersible pump was installed and pumped into a 10 cm pipe. Outlets were spaced 25 m in the irrigated area. The general configuration was a main line with 3 laterals crossing the main line. The reported cost for the system is 2145 RMB/ha. They currently dig small ditches by hand to distribute the water from the outlets to the adjacent border and furrowed area.

The benefits for the WSI is attributed to the following six factors:

1. Save farmland from above ground canals – 1.5%
2. Save water – 33%
3. Save electricity - 12.75%
4. Save manpower – 33%
5. Grain yield increase – 8.8%
6. Vegetable yield increase – 16%

The water table has dropped from 4 m depth to 10-11 m depth in the irrigated area. The surface irrigation is continued in the area where the ground water is of poor quality.

Dryland Agriculture

The Ministry of Agriculture emphasized the need to focus on the conversion from irrigated agriculture to dryland. It appears that this ministry has very little responsibility

for irrigation which is administered through the Ministry of Water Resources. They outlined four strategies or guiding principles for dryland agriculture:

1. Drought resistant crops (through biotechnology)
2. Conservation farming
3. Organic mulch (residue management)
4. Monitor soil water.

They expressed optimism that biotechnology can develop crops that can produce as much with significantly less water under drought conditions. They recognize that as demand for water by municipals and industry increase there will be less water for agriculture for irrigation.

The CAAS in their poster session review of their research showed pictures of corn where the seed is treated with a newly developed coating. The corn with the coating was much more productive than the untreated plot adjacent. It is unclear as to the exact mechanism or properties of this treatment.

Dryland conservation planter

A planter was developed that will not only plant the seed but also lay a plastic sheet to increase soil temperature and reduce soil surface evaporation. The planter also has mounted a water tank for wetting the immediate area of the newly planted seed. The water applied is equivalent to 5 mm of water. Since this is applied in the row with a partial wetting of the area near the seed, this is probably equivalent to 5 to 10 times that amount for effective use by the seed. Fourfold yield increases have been found with corn (from 750 kg/ha to 3000 kg/ha).

The benefit for the corn planted with the plastic mulch is to increase the soil temperature and allow an earlier planting in areas that have low soil temperatures and allow the corn to mature earlier and have higher yields. The plastic mulch is typically 0.6 m wide with an open area of 0.3 m. Thus, 2/3 of the area is covered with a plastic mulch. The cost of the plastic mulch is 20 RMB/mu. This compares to the cost of 120 RMB/mu for a wheat straw mulch. The straw has a much higher value than to be used for residue. This probably also explains the reported high erosion rates since the straw is not allowed to provide a residue cover with its high value.

Water harvesting for micro irrigation

This could be considered an irrigation technology. However, they presented it as way to increase yield where normal irrigation water supply from surface and ground water are not available. The concept is to construct buried cisterns in which rainfall is collected and stored. The micro irrigation system then is used with the water being supplied from above ground water tanks which gravity flow into the drip lines. This is obviously only possible with quite small fields. The CAAS illustrated a design and operation of one of these systems in a research greenhouse.

These same systems were also reported to be used for collection of water for domestic use and livestock water where surface and ground water supplies were not available. They are dug into the ground and often cement lined to prevent losses. Water is a short commodity in many places and they must conserve what they have in precipitation.

Soil Erosion

Soil erosion is a major problem in China, particularly in the Northwest and Southwest. Water erosion is a problem on 430,000 Km^2. A total of 1.6 billion tons of sediment go into the Yellow River and 400 million tons remain in the lower region. The detrimental effects are that:

1. Degrades the environment,
2. Results in economic and social costs, and
3. Causes flood control problems since the sediment has raised the stream bed above the adjoining area.

Since 1950, China has had soil erosion projects and brought 780,000 Km^2 under control. A total of 3.76 million Km^2 still has serious erosion problems. There is 1.96 million Km^2 south of the Great Wall and 1.8 million Km^2 north of the Great Wall that has serious wind erosion problems. They estimated that 2.1 million Km^2 can be brought under control. Terraces were constructed by hand but now tractors are furnished by the government. They are also encouraging the planting of grass and trees to control erosion.

Loess Plateaus

We visited the Loess Plateau north on Xian. The area is a clay soil that has been bench leveled and is growing dryland crops. The farmer that we visited was growing Chinese dates. He demonstrated the grafting of the date tree onto a smaller native date tree that provides a much better root system for using the soil moisture and prevent erosion. They are promoting the planting of trees in the area to decrease erosion. In Xian, the sky was always a haze. They indicated that much of this was soil and dust in the air from the Loess plateau. They feel with the terraces on the very steep slopes that they have the erosion under control. The berm between benches is almost vertical and it appears that by holding the water on each bench, there is very little evidence of erosion of these walls. They appeared to be in excess of 20 feet between successive benches or terraces. I noted smaller check berms on a terrace to assure capture of precipitation.

Irrigation and Management Research

A number of the organizations have research projects and locations that are of particular interest to the United States. Their research has many different disciplines involved. The irrigation system and water management research are relevant to this chapter. The following sections will identify the various organizations involved in research and that are interested in cooperative research. This cooperative research would be beneficial to the

United States by providing extra effort working on mutual problems. It would also assist in the development of much of our new technology to be able to extend our decision modeling to a wider range of conditions and make them more applicable to many of the conditions in the United States. The following sections will highlight the different organizations and the type of research that is being conducted.

Chinese Academy of Agricultural Science

Chinese Academy of Agricultural Science (CAAS) is the unique organization operating at state-level comprehensively responsible for both scientific research and technical development in agriculture. CAAS is composed of 38 organically assigned units (research institute or center) covering a wide range of agriculture from breeding and cultivation of grain crops, vegetables and fruits, to the environments and resources for crop growing, plant protection, to animal husbandry, agricultural products processing and to agricultural economy, regional planning and information. The research institutes intimately related to grain production and water resources utilization in agriculture include Institute of Crop Breeding and Cultivation, Germ Plasm Resources, Agrometeorolgy, Farmland Irrigation, Soil and Fertilizer, Agricultural Economy, and Agricultural Regional Planning.

CAAS has long paid great attention to the study area of crop plant production, water resources utilization in agriculture, and the relationship between them. The main aspects in which CAAS has played an important role in this country are:

- Strategic analysis and assessment for reference of the government on food security and supporting resource base of water, necessary measures taken to improve grain plant productivity, to develop both of rainfed and irrigated farming systems, and to maintain water quantity and quality available for agriculture.
- Regionally integrated planning, rational allocation and management of water resources for agricultural use including precipitation, surface water, groundwater and soil water towards the goal of environmentally sound, technically appropriate, economically valid and socially acceptable socio-economical development in arid and semiarid regions.
- Establishment of pilot projects in arid and semiarid regions mainly located in North, Northwest and Southwest China respectively in order to accelerate local prosperity of rural economy and to transfer multiple technologies in agronomy, soil conservation and efficient water management.
- Salt-affected soil reclamation with integrated measures tackling drought, water-logging and low fertility in Huang-Huai-Hai Plain.
- Techniques used in increasing grain yield and water management of dryland farming systems.
- Development of irrigation technologies with emphasis on design and development of equipment for water conveyance by pipe line, sprinkler irrigation and microirrigation.
- Development of locally adapted water-efficient on-farm irrigation methods and systems.

- Experimental studies on evapotranspiration of wheat, rice, corn, cotton and other crops grown in each province. Estimation of their irrigation water requirements. Establishment of water production functions and irrigation scheduling.
- Research on adaptive responses of main crops to water stress imposed at different growing stages and with different intensities, searching for the way of improvement of water use efficiency by crops.
- Modeling of ground water and unsaturated soil water movement including optimized site-specific schemes of agricultural water management of conjunctive use of surface and ground water.
- Design and construction of drainage systems with emphasis on open ditch system.
- Techniques of fertilizing for yield increasing, higher water and nutrient use efficiency and ground water quality protection.
- Identification of drought-tolerant germ plasm resources of main grain crops and development of drought-tolerant parent material of wheat and millet.
- Treatment and reuse of municipal sewage and industrial waste water for irrigation.
- Economical assessment of benefits and costs of on-farm irrigation systems. Study on irrigation water price. Agrarian behavior responsible to carrying out water-saving policy.
- Wide-spread extension and training programs of technologies, information and knowledge useful to sustainable development of agriculture involving higher grain productivity and water conservation.
- Performance of internationally collaborative research programs in this area.
- Postgraduate student training programs in this area.

A great deal of study in evaluation of water use efficiency (WUE) of various crop plants grown in different locations and regional irrigation water efficiency have been achieved or are being conducted by institutes of CAAS or with cooperation of other units outside of CAAS. Dimensionally, those projects are of region, county, extension district or experiment. Characteristically, they are for application or research. Examples of the projects of regional study are those about North and Northwest China under the National Priority Research Project during 7th and 9th 5-year Plan. More projects are of county and extension districts spread across Shanxi, Shandong, Henan, Hebei and other provinces granted by National Priority Research Project, Premier Foundation, Ministries of the State Council, and provincial authority. Basically, the examples mentioned above are of application. There have been research projects on WUE of crops conducted or organized by institutes of CAAS distributed throughout the country. Much of the research results were published in scientific journals or as a monograph such as *Atlas of Crop Water Requirement of China and Water Reguirement of Main Crop Plants and Their Irrigation in China.*

Farmland Irrigation Research Institute of the Chinese Academy of Agricultural Sciences

This institute indicated a desire to increase cooperation on their research program which has much similarity to programs in ARS. They are concerned about improved irrigation scheduling and have a 3600 weather station network in China. CAAS is not just a research organization but also must be concerned with technology transfer. They function somewhat as a consulting group by establishing technical groups to provide technical expertise as well as implementing technical upgrades.

They are focusing on two boundary layer problems with respect to crop production and water use. The first is the micrometeorology of the canopy and the atmosphere. The second is the soil surface and into the root zone. They are counting on biotechnology to provide crops with increased drought resistance. They are particularly interested in using waste water for irrigation. Beijing has a canal that carries untreated sewage directly to the ocean and they are questioning how they could effectively use this as a resource.

The following is the information in a brochure that they provided.

FARMLAND IRRIGATION RESEARCH INSTITUTE
Chinese Academy of Agricultural Sciences and Ministry of Water Resources

The Farmland Irrigation Research Institute (FIRI) was founded in 1959. It operates as a national irrigation and drainage research organization under the Ministry of Water Resources, PRC and the Chinese Academy of Agriculture Sciences.

I. Research Direction and Other Functions

Research efforts of the FIRI are directed to irrigation-drainage-oriented applied research and relevant basic research of national importance, with emphasis being placed on the solution of major scientific and technical problems facing China's agricultural irrigation and drainage, and on the study of theories, methodologies and development strategies in related disciplines. Meanwhile, great attention is paid to the application and extension of research achievements, to the coordination of key collaborative research projects nationwide, to domestic and international academic exchanges, to technical personnel training and to the editing and publication of professional journals and monographs.

II. Technical Manpower and Specialized Academic Groups

The FIRI now has an academic and administrative staff of 178. Of the 114 research members, 35 are senior researchers, 52 middle-ranked researchers, and 37 junior researchers, graduating from 23 specialties such as irrigation and drainage engineering, agronomy, hydrogeological engineering, soil agrochemistry, water resources engineering, farming meteorology and so on. Many of the researchers have either a doctor's degree or a master's degree. In FIRI, outstanding research scientists (26) have been awarded a special governmental allowance and scientists (8) have been commended in other forms by the State Council of PRC. There are 11 tutors for doctoral and master candidates.

The FIRI is in charge of the Working Group on Micro-irrigation under the Chinese Hydraulic Engineering Society. It also plays a leading role in the following academic organizations including China Working Group on Sprinkler Irrigation, China National Network of Technical Information on Ground Water Resources, and China National Network of Irrigation Experiment. In addition, a branch of the Henan Hydraulic Engineering Society is established in this institute.

III. Main Departments and Their Functions

A brief account of main departments and their functions is given as follows:

1. The Divisions of Research Programs Management. It is the department responsible for the organization and coordination of research activities inside the FIRI; for the coordination of inter-institution collaborative research projects on irrigation and drainage throughout the country; for international academic cooperation and exchanges; and for technical training programs.

2. The Center for Science and Technology Programs Development. It offers consultancy services making use of the considerable expertise of research staff and manages several companies wholly owned by the FIRI.

3. The Research Department of Crop Irrigation. In this department, attention is given to studies of crop requirements, the rule of water consumption by crops, the procedure and principle of water-efficient irrigation, and the forecasting techniques of irrigation.

4. The Research Department of Irrigation Techniques. Research of this department is placed on studies of the innovation, new equipment and technologies of various irrigation methods including surface irrigation, sprinkler irrigation and micro-irrigation, and on relevant theories.

5. The Research Department of Hydromelioration. Studies of this department are directed to the mechanisms of the movement of salts in soil and ground water, to integrated reclamation measures for low-middle yielding fields relying mainly on irrigation and drainage techniques. Emphasis is placed on theories and practices of farmland drainage.

6. The Research Department of Irrigation Water Resources. In this department, efforts are made to study theories on the development, utilization, optimal allocation and management of irrigation water resources.

7. The Department of Technical Information Research and Literature Publication. It is engaged in studies and exchanges of technical information on irrigation and drainage, management of a library, and the editing and publication of a quarterly journal "Irrigation and Drainage" and other monographs.

8. The Shangqiu Comprehensive Experiment Station. It is used as an experiment base to conduct studies on integrated control techniques for low-middle yielding fields in the Huang-Huai-Hai Plain and on measures for sustainable agricultural development in problem areas.

9. The Test Center for Quality of Water-saving Irrigation Equipment, the Ministry of Water Resources. It is the section authorized to evaluate 135 technical parameters under 7 categories including sprinklers, sprinkler irrigation units, emitters in micro-irrigation, materials and fittings for irrigation pipe and tubing, pumps, water quality, and soil.

IV. Test Fields, Laboratories and Other Facilities

The headquarter of the FIRI covers a total area of 11.5 ha and has a building area of 26,000 m^2.

Main test fields and laboratories include:

O The Test Field for Sprinkler Irrigation. Covering an area of 7,200 m^2 and paved with precast slabs, this field is satisfactory for testing hydraulic characteristics of sprinkler heads and irrigation pipes, and experiment with various combinations of wetting patterns for low-moderate pressure sprinklers.

O The Hydraulic Laboratory of Sprinkler and Micro-irrigation. This lab has an area of 1,296m^2 and can be used for experiments on hydraulic characteristics of sprinkler heads with a short to medium range of wetted diameters, on sprinkler irrigation pipes, on hydraulic characteristics of micro-irrigation and on performance test of irrigation pumps. Measurement of air temperature, humidity, water temperature, operation pressure of sprinkler and micro-irrigation systems, and flow rate and water distribution is automated. Data self-recording and processing units with test result printers are provided.

- The Test Field for Crop Requirements. In this field, a motor-operated rain shelter is installed, with a coverage of 1,334m^2 that can be shielded from rain. Equipped with 36 pits for measuring soil water content, 2 hydraulic evapotranspirometers, necessary meteorological observation instruments, a runoff experimental plot and relevant recording devices, telemetering geothermometer and other portable measuring apparatus, the field is well adapted to experiment on crop requirements, the rule of water consumption by crops and the study of proper soil water content. It is also suitable for the observation of rainfall infiltration and available rainfall, and for multi-purpose studies on SPAC system.

- The Observation Fields with Lysimeters. Installed with the most sizable lysimeters in China covering an are of 400m^2, 12 test pits in the size of 3m X 3m, 50 measuring cylinders and a meteorological observation plot, the field is adaptable for the observation and simulation of crop requirements, evaporation,

soil water potentials at different layers, various depth to water table, and salt-water transport of soil in bare or cropped land, and for experiments on the interaction of water and fertilizers.

Other Facilities include the Laboratory for Surface Irrigation, the Laboratory for Seepage Test, the Laboratory for Soil Physics, the Laboratory for Resistance-reactance Network Analogue, the Laboratory for Resistance-capacitance Analogue, the Laboratory for Testing of Material Strength, and the Multi-purpose Laboratory.

Besides, there is a training building which accommodates 140 trainees with lodging and has a lecture hall seating 300 people attached to it, facilitating collaborative research, academic exchanges and technical personnel training.

V. Scientific Apparatus Available

The FIRI is backed up with a large number of instruments or equipment necessary for research and experiment, including soil moisture extractor, neutron probe, high speed centrifuge, time domain reflectometer, soil salimeter, automatic tensiometer, canopy analyzer, electronic scale with an accuracy of 1/100,000, automatic meteorological observation station, subterranean line detector, leaf area meter, test stand for pumps, and electronic computers.

VI. Achievements in Scientific Research

Since its foundation, the FIRI has accomplished 131 research projects of which 3 were granted awards by the Central Government, and 42 won prizes from relevant commissions, ministries and provincial governments.

In particular, FIRI's research findings in techniques such as sprinkler irrigation, micro-irrigation and irrigation by low-pressure pipes have been extended to many places over China and gained remarkable socio-economic benefits.

In FIRI, focus of studies on water-efficient agriculture has shifted from engineering-oriented techniques to integrated measures involving aspects such as engineering, agronomy, biology and management and some breakthroughs have been made.

The application and extension of research accomplishments such as the Comprehensive Control of Low-middle Yielding Land, the Improvement of Black Shachiang Soil, and the Amendment of Waterlogged Rice Field in Southern Parts of China, have made great contributions to the increase in agricultural production at places in question and have been welcomed by farmers.

Other research results achieved by FIRI's scientists such as the forecasting techniques of salt-water movement of soils and the isograph of crop requirements for China's main crops have laid scientific foundations for regional development, water resources planning

and the design of irrigation systems and have made sound social benefits because of their application in agricultural practice.

VII. International Exchanges and Cooperation

Since 1980, some 30 researchers from FIRI have gone abroad for advanced studies, on investigation tours or participation in international conferences. During the same period, about 150 scholars, experts or officials in 40 teams from 24 countries or international organizations such as Australia, Britain, France, India, Japan, Russia, the United States, the World Bank, and so on have come to his institute, some for a visit, some on study tours and still others for lectures.

Yucheng Comprehensive Experimental Station, Chinese Academy of Sciences

1. Natural Features

Yucheng Comprehensive Experimental Station, Chinese Academy of Sciences (CAS) is one of the laboratories of the Institute of Geography, CAS. Headquarters of the station is located in Beijing. The experimental sites and it's laboratories are located in the southwest of Yucheng City, Shandong Province (latitude: 36 degrees 57' N; longitude: 116 degreess 36'E; altitude: 20m). The climate in this area is a warm-temperate and semi-humid monsoon climate. The average annual temperature is 21 degrees C. The monthly highest average temperature is 26.9 degrees C (July). The monthly lowest temperature is –3 degrees C (January). The maximum temperature is 42 degrees C. The minimum temperature is –25 degrees C. The annual sunshine-hour is 2640 H. Accumulated temperature over zero degree is 4951 degrees C. The frost-free season is 200 days. The annual average precipitation is 610 mm. The ground water level is 2 m. Soils in this area are aquatic soil (Chao soil) and salinized aquatic soils (Salinezed chao soild). The general feature around the station represents Huang-Huai-Hai Plain in both physical conditions and agriculture.

The fundamental researches on irrigation in Yucheng Comprehensive Experimental Station are being done at the experimental station located in Yucheng City. The applied research on irrigation (microirrigation) is being done not only in Huang-Huai-Hai Plain but also in other places in China according to the research funds supplied.

2. The History

Yucheng Comprehensive Experimental Station was initiated by the Institute of Geography, CAS, in 1979, and was officially founded in 1983. It was assessed as one of the open experimental stations for both domestic and foreign scientists in 1988. It was approved as one of the basic stations of the China Ecosystem Research Network (CERN) in 1992.

3. Major Research Orientation and Realms

The main research orientation of the station focus on the problems of rational use of agricultural resources including water, land, climate, and biology, and the methods for comprehensively managing drought, waterlogging, salinization, and sandy problems.

The major research realms are as follows:

- Agroecosystem engineering which includes the structural functions, measures and stability of agroecostystem.

- The regularities of energy transformation and matter transferring in agroecosystem such as mechanism, regularities and controls, etc.
- Water transformation mechanism in agroecosystem including the mechanism of evaporation processes, crop water requirement and consumption and the ways to improve water use efficiency.

- Experimental remote sensing in soil-plant-atmosphere continuum which include surface radiation, wave spectrum, soil water and crop yield predicting models.

- Microirrigation, sprinkler and water-saving surface irrigation including irrigation scheduling, deficit irrigation, regulated deficit irrigation, methods and computer software for design and management of irrigation systems, fertigation, etc.

4. The Long-term Observation Items

- Field evapotranspiration from farm land.

- Crop water requirement and consumption, water use efficiency and rational management of ground water.

- Soil water measurements by means of neutron probe and tensiometer, etc.

- A 60 m tower with a microcomputer data logging and processing system for measuring the gradient of temperature, humidity and wind at seven levels.

- Remote sensing experimental system including 30 m high tower equipped with infrared and thermometers, multiwave cameras and a microcomputer system for measuring infrared, multiwave characteristics and surface factors in soil-plant-atmosphere continuum (SPAC).

- Crop photosynthetic, mainly by means of eddy correlation to measure evpotranspiration, sensitive heat flux and CO2 flux, etc.

- The other observation sites including artificial rain and comprehensive water movement observation sites, etc.

5. Data Collection

The experiment data collected since the establishment of the station is as follows:

- Ten years meteorological records with the standard of national meteorological stations.
- The status of soil water.
- Ground water level.
- Components of solar radiation balance including global solar radiation, direct solar radiation, diffusion, albedo, net radiation, ultraviolet and infrared.
- Field microclimate data including air temperature, humidity, wind, surface temperature and soil temperature.
- Evaporation from free water surface with various types of evaporation pans.
- Advanced lysimeter for measuring field evapotranspiration.
- Remote sensing and soil water.
- Evapotranspiration and crop water requirements under microirrigation, sprinkler irrigation, etc.

6. The Cooperative Research

In recent years, over 200 scientists and governmental officials from about 30 countries have visited the station for academic cooperation and exchange.

Cooperative projects with the U.S.A, Australia, France, Israel have been conducted. The Scientists from 20 institutes, CAS or related universities in China are jointly doing the research works with the researchers of the station. The station has good relationship with the local people and governments. The rescarchers of the station solve problems in agricultural and supply information of new technology to the local people and governments for sustainable development of agriculture.

The cooperative projects are:

- Remote sensing reflectance experiment of canopy in two dimensions and two directions of multispectrum.

- Ecological environment during fluorescence and model prediction of the crop yields by pollen flux.
- Basic application studies on water-saving agriculture in Northern China.
- Studies on regional evapotranspiration.
- Manufacture and installation of large weighing lysimeter.

Recently, there is discussion of cooperative research subjects on micoirrigation scheduling, fertigation, deficit irrigation, regulated deficit irrigation with professors from USA, Israel and Japan.

7. Present Conditions

This station has an area of 15 ha for plot experiment and 5 km^2 for small catchment experiment. There are modern and fully equipped instruments and facilities on the research of soil-plant-atmosphere continuum and water cycle, water balance and irrigation in the station. Most of the observation sites and instruments for the researches in the station have been equipped. They are as follows:

- Field evapotranspiration site.
- Crop photosynthetic site.
- Field water experimental site.
- Irrigation experimental site.
- Measurement system for the factors for temperature, humidity, wind.
- Remote sensing experimental site.
- Comprehensive experimental site for artificial rain and soil water movement.
- SE-590 CCD Spectro-Radiatiometer System with 256 wave bands.
- Soil nutrient balance observation site.
- Bowen-Ratio-Energy Balance System (BREBS).
- Hot wire anemometer.
- The instruments for measuring solar radiation.
- Leaf area measurement instrument.

- Lysimeter with an area of 3 m^2, the depth of 5 m and the weight of 36 tons.

The Experimental station also has a soil physical laboratory, a physiological laboratory, a chemical analysis laboratory, an irrigation laboratory, a computer room, an administrative building, dining room and a facility for housing experts.

The Station has 23 permanent staff dealing with the research subjects mentioned above.

This group is very interested in cooperating with US researchers and has done so in the past. They have interacted with the U.S. Water Conservation Laboratory.

Department of Irrigation and Drainage, Ministry of Water Resources

The Department is specialized in the research and popularization of irrigation and drainage technology, planning and design of irrigation engineering. The main research activities are: water-saving technique, drainage technique, low-and-medium-yield land amelioration, groundwater assessment and exploitation, soil water and salt dynamics, radial collector well, rubber dam, irrigation management and water environment in farmland.

The Department includes a drainage laboratory, a material testing laboratory, a physical and chemical laboratory and an irrigation and drainage equipment testing hall. Besides, a comprehensive water-saving experiment base with a 12 ha area is located in the suburb of the city. Sophisticated instruments including neutron moisture meter, TDR, rainfall simulator, radial collector well model are equipped in these laboratories for experimental uses.

There are 33 technical staffs in the Department, including 17 senior engineers, among them 6 possess doctor degree and 13 possess master degree. The Department consists of 5 research divisions, 2 centers, a company and a factory.

The Divisions and their research responsibilities are as follows:

No. 1 Water-Saving Research Division: research and extension of sprinkler irrigation, drip irrigation and sub surface irrigation.

No.2 Water-Saving Research Division: research and extension of basin irrigation, furrow irrigation, laser leveling, canal lining, low-pressure sub-surface pipeline and comprehensive soil and water management.

Irrigation Water Management Division: research and extension of irrigation district and catchment water management, computer and GIS application on irrigation and drainage management as well as canal system automation.

Drainage and Water Environment Division: research and extension in sub-surface drainage, radial collector well drainage, amelioration of saline and alkaline land, and assessment of farmland water environment.

Engineering Design Division: design and consultation service on sprinkler irrigation, drip irrigation, rubber dam, gate and dam, canal lining, low-pressure pipeline and sub-surface drainage pipeline.

Centers:

O Center of Quality Inspection on Irrigation and Drainage Equipment

O Yanshan Drip Technology Research Center Company:
--Beijing IWHR Water Engineering company

Factory: --Water-Saving Factory

More than 170 outstanding achievements have been attained by the Department in the recent years, among which 6 won the State Prizes and 17 won the Ministry/Province Prizes of the Progress in Science and Technology. The Department is approved by the State Science and Technology Commission as the technical support base of the following technology:

Sprinkler, drip and micro irrigation in arid and semi-arid areas

- Low-pressure plastic pipeline technology
- Rubber dam technology
- Drip irrigation facilities
- Application of thin-wall plastic pipe
- Water-saving technology for cash crops

The following products are manufactured by the Department factory:

- Surge irrigation equipment
- Drip irrigation equipment
- Gated pipe irrigation equipment
- Radial collector well equipment
- Software for irrigation water management.

Chapter 6

Water Resources

Vernon R. Schneider

China is blessed with abundant water resources. Precipitation ranges from more that 1000 mm. in the southeast to less that 100 mm. in parts of the northwest. However, like the United States, there is not always sufficient water to meet the demand in all locations. Historically, China has developed a variety of water transfer schemes to move water from water-rich areas to water-poor areas. In fact, there are three such transfer schemes currently on the planning table for considered during the next half century. China is also blessed with the largest population of any country in the world, or some 1.2 billion persons that is expected to grow by 260 M in the next two decades. This is essentially adding a country the size of the United States, which is the 4th largest country in the world today. China is also beset by floods and droughts which have caused serious problems for agriculture when they occurred.

Water Demand

Most people we visited indicated that there is a need for much more water than is generally available in China. There is abundant evidence of demand for competing uses, such as urban and agricultural. This was evident in the Beijing municipality. We did not get a lot of quantitative data on how much more water is needed for specific purposes, in other words, about what demand for water is and what are the trade offs. However there were many indications of these needs.

Evidence for the demand for additional water includes the availability of arable land that could be irrigated but water is not available. In Wuqing county, the officials indicated that they were only able to irrigate 60 percent of the land because of insufficient water resources.

In Wuqing, they actually reported demand and indicating that they were water short. They report that the demand for water in the county was 520 million cubic meters but the supply was only 90 million from ground water and 160 million from surface precipitation, which left a deficit of 270 million The main conclusion was that the county was water short in the sense that if they had more water they could irrigate more land. So they took two basic measures. First, they have been tapping into the two canals, which run through the county, i.e. they are using wastewater for irrigation. Second, they have implemented the water saving irrigation program. They have applied water saving technology to 31 percent of their irrigated area (28,667 hectares / 91,600 hectares of total irrigated area). The county Water Bureau is making a ten-year long term water plan out to the year 2010. First, they want to double the area covered by water saving technology. Second, they want to expand the storage capacity of their reservoirs from 75 million cubic meters to 100 million cubic meters. When upstream runoff flows through the

county during the heavy rains in July and August some of this runoff is diverted and stored for later use.

Water saving agriculture was most frequently mentioned as the response to the shortage. The Yellow River does not flow to the sea year round. In response, there is new permitting system in the Yellow River has the potential to rectify the water allocation process and assure that adequate water resources are available or at least equitably distributed among the users whether they be upstream or downstream in the system. Data and reports that might be available from the Bureau of Hydrology would be extremely valuable. We had an interesting discussion in with Mr. Liu of the Yellow River on the subject of this allocation.

Ground water overdrafts in the North China Plain are now common knowledge. The extent and severity of those overdrafts is being documented.(see Chapter 4). The water was probably exploited for a short term gains. People the Ministry level seem to believe that dryland farming and water saving agriculture will replace irrigated agriculture as it is currently practiced in North China.

Mr. Feng in the Ministry of Water Resources reported on studies indicating the the total water resource is the Yellow River Basin was 50 B cubic meters. Of this amount 20 B cubic meters was used to flush sediment from the system. They estimated that much of that water could be recovered if all lands were stabilized in the Yellow River basin. In order to accomplish that goal, there is a plan to in face stabilize the basin by the year 2050. Given the size of the Yellow River Basin, it is an ambitious plan. Mr. Feng was interested in sharing ideas on economic techniques for stabilizing lands.

Water Availability in All Categories.

China's population is about 1.2 Billion while the population of the United States is about 0.27 Billion. In other words, China's population is 4.5 times larger than that of the United States. The overall volume of water resource of the United States and China are nearly the same. However, the per capita water availability per person in the United States is about 9400 cubic meters while China averages about 2300 cubic meters per person. There are wide regional variations. In the Hai Basin it is 430 cubic meters per capita. In the North China plain, [surface] water availability per capita drops to a staggeringly low 225 cubic meters per year, while in southeastern coastal China it is as much as 32000 cubic meters per year.

China has moved to develop the various sources of water.

Rainfall

China is using various rainfall harvesting techniques including cisterns to collect water in water short areas.

Surface Water Runoff

China is developing reservoirs to store surface water where possible. They are also looking in additional South to North diversions which move water from water rich areas to water poor areas. Terracing is be used to reduce runoff, increase infiltration, reduce erosion, and at the same time provide water for agriculture. While the United States is believed to have built out all of its major reservoir sites, we don't know about the potential for additional surface water storage in China.

Ground Water

Groundwater is be exploited where available. The North China Plain is overdrafted and irrigation practices will have to change.

Reserved Water

Reserved water or water stored in reservoir is to be carried over to next season to provide water when rainfall decreases. The rain normally occurs in July and August. Water is used to either get crops started or to supplement variations in the rainy season.

Recycle Waste Water

Water available for reuse. This may be a future water resource for China. As more treatment plants are built, waste water can be recycled for industrial and agricultural use.

Water Use

It has been widely hypothesized that China is suffering a water shortage that will ultimately limit its ability to produce food particularly in the North China Plain. In that area we see that the groundwater is being dangerously overdrafted and in some areas may be no longer able to be irrigated for the lack of water. This theme was stated at each stop along the way. Data were presented to prove the point.

Yet the point was not proven. There is a need to quantify the loss and the impacts of the loss of food crops from the North China Plain if there was a massive conversion to dryland farming.

The World Bank (1997) reports that overall water demand (use) has increased 68 percent in Northern China between 1980 and 2000. It estimates that it has increased 63 percent in the Hai River Basin, with the most significant increases in municipal (172%), industrial (375%), and rural domestic use (146%). Irrigation demand increased only 20 percent.

Increasing Supplies

Diversions

There are three proposed south to north diversions from the Yangtze to the Yellow River. They are the west, middle and the east. Prof. Wang described them to us and offered opinions as to their feasibility. The beneficial user changes depending on the choice. The west is the environment and ecology, the middle is urban and industrial and the east is a mix of urban-industrial and agriculture. The projects are expensive, require great amounts of electrical energy and may have varying impacts on the environment. There is a team studying each alternative. Their work will not be finished for more than 7 years. In the best scenario, no alternative can be completed for more than 20 years. Obviously this is not a short term solution to any water problem. The middle solution could bring about half of the water requirement to Beijing that is needed, but not all the water will go to Beijing.

Water Saving Agriculture

Engineering works to save water during times of surplus and by on farm irrigation practices. As described by the Chinese, water saving agriculture is almost everything you do to reduce the use of water, such as using spray instead of flood, and applying less water. The example of the reduction in water applied to rice that we heard in Tianjin is a good one to illustrate this point.

Water Reuse.

This is applying waste water to plants. It is not obvious how widely this is practiced. I suspect that the water treatment infrastructure is not in place to make this really possible. This was not widely discussed during our visit but vast quantities of untreated water appear to be flowing to the sea. In the case of Beijing, it may be as much as 2 B cubic meters per year. Consider it to be a resources available for exploitation. Major investment would be needed to clean up the urban and municipal water however.

Agricultural Practices To Save Water

A variety of techniques and practices were mentioned.

- Use organic fertilizer to build up the soil's capacity to absorb water
- Use plastic film conserve water and raise soil temperatures
- Use organic mulch
- Use furrows on the contours to save water (shui ping gou)
- Seed crops in the bottoms of deep furrows
- Seed coatings
- Adjusting the sowing time to take advantage of rainfall in July and August.

Wiberg (1999) suggests the following:

Improve irrigation efficiency which is reported to be operating at only 30 percent efficiency.
Repairing older water supply systems and updating facilities to be more efficient.
Fees for urban water use consistent with the cost should be imposed.
Water transfer is an option to move water to the water short north
Desalination is too expensive to be widely considered

Flood and Drought Planning and Management

Bioengineering

This included the development of salt tolerant or drought resistant species.

Ground water

The use of ground water varies widely. In some areas it is a primary source and in other areas it is supplement in case surface water supplies fail or are inadequate in a particular year.

Dryland Farming

Dryland farming uses available moisture so would not have to rely on supplemental irrigation.

Drought Resistant Crops

Chinese dates were planted that have a root system that efficiently collects water over a wide area and may even help to reduce erosion.

Adjusting Planting Dates

Time the planting of crops to take advantage of the rainfall in July and August. This is being done in some areas.

Floods may not be as much of an agriculture issue as much as are droughts. Of course, when floods occur and crops are being grown on flood plains, they can be destroyed or damaged. Engineering works such as flood control reservoirs and levees are needed to provide protection.

Soil and Water Conservation Methods and Goals.

This involves stabilizing soils to reduce erosion. The Chinese site the 20 B cubic meters of water needed to flush water from the Yellow River as a case that if the watersheds

could be stabilized and the erosion was reduced this water would be available for other use. It may be true in part but in reality the terracing used in stabilizing the watersheds will tend to capture water into the soils which could reduce runoff. Trees and grass planted to aide in the stabilization also have a water requirement. Soil and water conservation is important should go on. The outcome may not be as much water as projected.

This was described in great detail by Mr. Feng at the Ministry of Water Resources.

Monitoring and the Collection of Data.

Wherever we visited we were told that the Ministry of Water Resources was responsible for collecting data on water resources and hydrology. This ministry has the charge to monitor surface and groundwater and to analyze data and publish the reports. It was not evident how widely the data are distributed and made available to other Ministry's such as the Ministry of Agriculture. We did not get much information on this item. Key issues are documenting an documenting available water resources and water shortage. This could be defined as inability to meet demand.

Factors Limiting Change.

These include the land ownership issue and the periodic land redistribution's. The size of plots is on average small in eastern China, so applying cultivation techniques amenable to large-scale farming operation are currently not feasible. Somebody pointed out the limits of this and suggested that better job of furrow irrigation was all that could be reasonable expected. In Gao Zhunag Village, we saw case where the farmers had elected to pool there lands and farm them as several large fields. This provided the opportunity for using more mechanization in all aspects of farming. It also reduced the labor needed to produce the crop, freeing up people for other enterprises.

Opportunities for Collaboration

There are many opportunities for technology transfer and opportunities for scientists looking to work with colleagues in the United States. There were some possible other types of opportunities such as the use of filter clothes in the industry to stabilize the watersheds.

We might organize them as follows:

1. Technical exchange
2. Scientific exchange
3. Commercial sector

Equipment that can be applied in China and be cost effective is of great interest. Apparently United States manufacturers can't make money in China because local enterprises simply copy the devices and use it.

China is also looking for ideas for things that are working in the United States and could be exported and made to work in China.

Recommendations of Issues To Consider for Future Trips.

Dryland farming experts to share knowledge. Could technologies that were rejected in the United States as too labor intensive be okay for China where labor is cheaper?

Water demand versus the ways water is being used. Realizing that agriculture is the key issue here, the water short Beijing province could be an interesting study in balancing supply and demand among competing uses.

Maximizing agriculture in other areas of China to offset losses of production in the North.

Climate forecasting activities are important in anticipation of flood and drought and its consequences. In areas where several crops are grown annually, seasonal forecasts 3 to 6 months out are beginning to be relatively accurate, so that wider use of this technology and it's use in decision making by farmers may be practical in deciding which crops to grow.

Getting through droughts involves a certain amount of emergency management type of planning in terms of buying food and positioning it for use in case of a drought.

Issues to Consider

1. Value of upland water versus downstream water.
2. Flood versus drought in the Central and South areas of China.
3. Dryland farming in China.
4. Develop joint projects.
5. Design the conference that is to be held at the end of four years. This could give a focus for the activities.
6. Technology as a focus. How are on-farm devices and equipment for saving water are developed and tested?

References:

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Chapter 7

The Hai Basin

Frederick W. Crook

The Haihe River Basin Water Conservancy Commission

On Monday afternoon, September 20, 1999 the Team met Ms. Ma Xiu-qing from the commission. She has worked there for many years and said the commission has a staff of about 300 people. She gave the Team 3 brochures, one entitled "Haihe," was 32 pages; a second was a paper prepared by Li Yan-dong and Ma Xiu-qing, Department of Planning and Scientific Research, Haihe River Water Conservancy Commission, "The Influence of Deficiency of Water Resources in the Haihe River Basin of Social Economic Environment and Its Countermeasures," paper given to the USDA Water Team, September 1999, 8 pages.

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The Haihe River Basin Water Conservancy Commission was established by the Ministry of Water Conservancy on April 1, 1980. The Commission has jurisdiction over the following units.

- The Administrative Bureau of the Zhangweihe River and Southern Grand Canal.
- The Administrative Bureau of Water
- The Diversion Project from the Luanhe River
- The Administrative Bureau of the Lower Reaches of the Haihe River
- Management of the Tianjin Projecting and Design Institute for MOWR.

There are two main river systems in the basin the Haihe and the Luanhe.

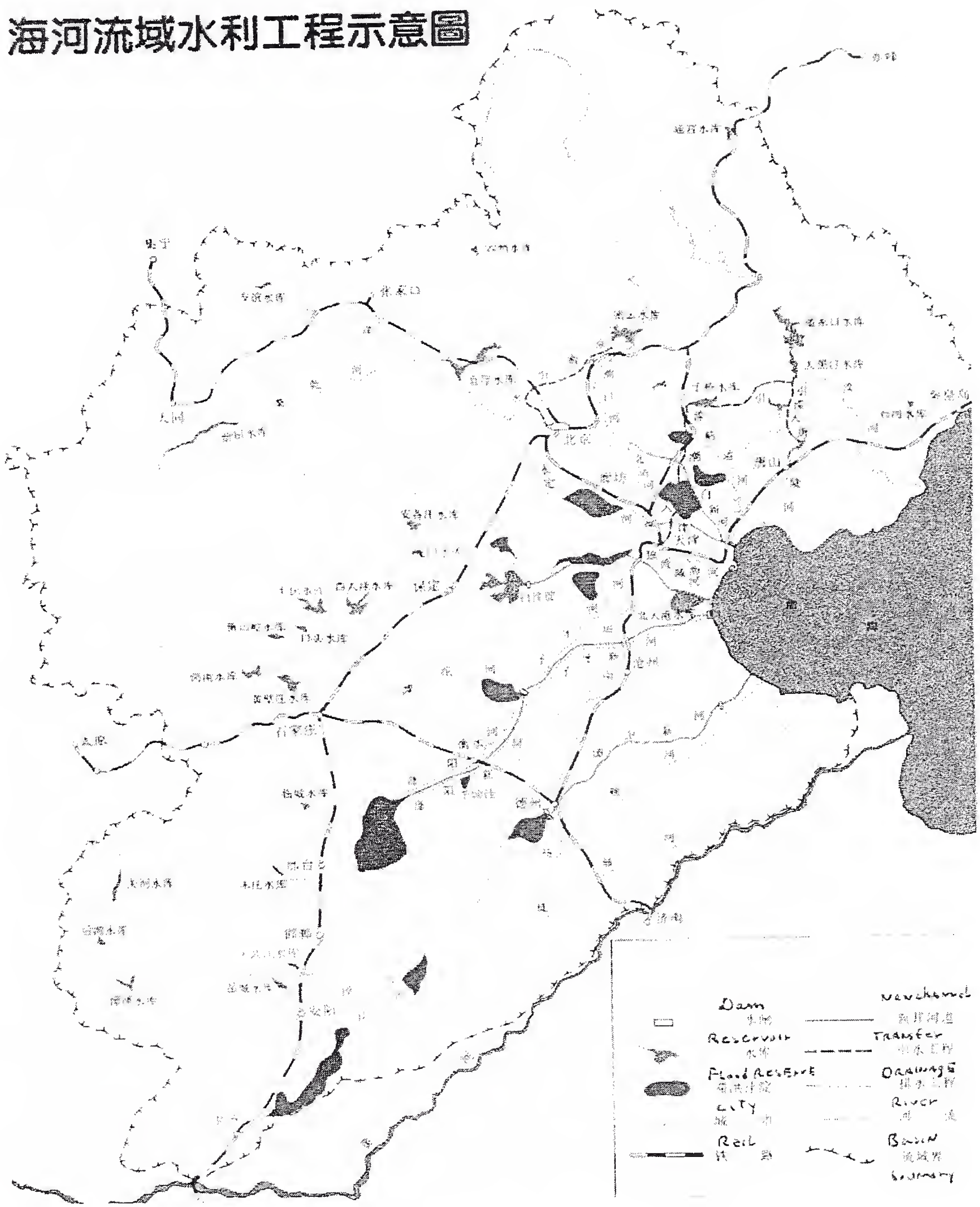
> Haihe river tributaries include the Jiyunhe, Chaobaihe, Northern Grand Canal, Yongdinghe, Daqinghe, ziyahe, Zhangwei he, the Southern Grand Canal, Tuhaihe, and the Majiahe.
>
> Ms. Ma's brochures did not list any tributaries for the Luanhe river.

Ms. Ma's brochures also note that at Tanggu where the Haihe River enters the Bohai gulf there is a dam and 8 large sluice gates, which are designed to save water, save flood waters, and prevent sea water from entering the mouth of the river (Haihe, p. 16).

The basin has 318,000 square kilometers, 120 million people, and 11 million hectares of arable land. Three rivers in the basin reach the sea separately: the Hai, the Tu hai, and the Ma jia. The basin receives an average annual rainfall of 548 mm of precipitation a year but the annual range is from 200 to 1000 mm. Eighty percent of the precipitation falls in the months from June through September. The basin has 6.42 million hectares of effectively irrigated area.

Map 7-1—Map of the Hai river basin.

Map 7-2—Water conservancy structures in the Hai basin.



Frequency of Floods and Droughts

Ms. Ma said they have data on floods and droughts from the 17th century. The basin has a serious drought once every 40 years, a large drought once every 5 years.

Water Resources and Use

Ms. Ma reported that the average water resource of the basin is 41.9 billion cubic meters of which 26.4 billion comes from surface water and 27.5 billion from ground water. She mentioned that 12 billion cubic meters of water is reused.

With regard to use she said the following:

15 billion cubic meters	is used from surface water	43 percent
22. "	is used from ground water	57 percent
39.7 "	total use	

With regard to sector water use:

27.1 billion cubic meters	agriculture use	68 percent

of which:

16.2 billion cubic meters	comes from ground water	60 percent
11.9 "	comes from surface water	40 percent

The "Haihe" brochure says that the long term average use rate for surface water is 56 percent; 72 percent in a normal year like 1978; and 95 percent in a dry year like 1984. The long-term average use rate for ground water was 72 percent, 73 percent in a normal year like 1978, and 82 percent in a dry year like 1984 (Haihe brochure, p. 6).

Wells

The "Haihe" brochure says that wells were first dug in the basin to water fields several millennia BC. Now there are 800,000 wells in the basin, which irrigate 4.13 million hectares of land, which is 64 percent of the total irrigated area in the basin ("Haihe," p. 23).

Planning

Ms. Ma said they formulate plans, which coincide with the five-year economic development plans. Currently they are in the 9th Five-Year Plan. They are making plans now for the 10th Five-Year Plan (2001-2005) and for the decade 2001-2010.

The basic function of the commission is to make water use plans and to coordinate water conservancy efforts among the provinces in the basin.

Ms. Ma said the commission manages water use out of two reservoirs: the Pan jia kou in Hebei province which allocates water to Tianjin and to Beijing; and Yue Cheng reservoir which distributes water to Hebei, Shanxi and Henan.

Water Resource Data

Ms. Ma said the commission does not have time series data. The provinces have it. Team members noted that in the 1991 Water Resource Yearbook there was detailed data on the Hai basin but that in subsequent years the basin data series was not continued. Has the commission stopped collecting data? Ms. Ma said that the data exist but with less budget and fewer staff it is not possible to print up the data each year. Mr. Yang said that maybe the data would be printed on a periodic basis (perhaps on a 5 or 10 year basis).

Provinces have the responsibility to collect water resource data.

Falling Ground Water Tables

The Team asked if users in the area could continue to exploit the use of underground water. Fifty percent of the water use comes from ground water, can the pumping continue? Ms. Ma said they are trying to control the pumping, for example they issue water use permits.

Ms. Ma described the underground aquifer. The top layer is a fresh water layer (sometimes polluted from sewage water). The next layer has salt water (from the ancient sea). She said the Yellow River used to enter the sea in the Tianjin area and they found alluvial file down 2,000 meter to bedrock. The filling trapped some salt water. Below the salt water layer is a deep layer of fresh water.

Ms. Ma said the water table in Tianjin, Cangzhou, Hengshui and Dezhou has declined to below 70 meters from the surface of the land. This over drafting of under ground water resources has led to land subsidence which is particularly important in Tianjin which registered subsidence of 2.6 meters. This is a problem since he city is close to being at sea level already (Li Yan-dong, p.3).

Pollution of Underground Water Sources

Ms. Ma said that the situation is getting worse. It is most serious in the eastern part of the basin. Wastewater travels down stream, for example sewage from Beijing. On the one hand this water can be used to solve downstream water deficit problems, but on the other hand this water brings pollution problems. Each year 6 billion cubic meters of industrial wastewater and domestic sewage is discharged into river courses without treatment (Li Yan-dong, p. 3). Ms. Ma said this polluted water has let do pollution of shallow underground aquifers.

The 1998 Water Resource Yearbook reports that 63 percent of the underground water resources in the Hai basin have been polluted (page 126).

South to North Water Transfer Projects

The Haihe brochure page 26 reports that water can now be transferred from the Yellow River to the Baiyang Reservoir east of Baoding City (Hebei province) and then by canal onto Tianjin. The length of the canal is 600 kilometers and can handle 150 cubic meters per second and presumably over a year could transfer 1.25 billion cubic meters of water per year. We got the impression from Ms. Ma that while this capability exists and the Commission has the right to a certain amount of water from the Yellow River, in fact they are now not getting water from that source. Rather they are counting on getting water from the Luanhe River for use in Tianjin.

There is a proposal underway to use the Grand Canal to transfer water from the Yangzi River at Yangzhou to Tianjin. The length of the canal would be 1,170 kilometers. This project is now in the planning stage. Water from the Yangzi River will have to be pumped up 40 meters and a siphon will have to be built to go under the Yellow River (Haihe, p. 26).

Gap Between Water Supplies and Demand Forecast

The Li -Ma paper presented some forecast numbers out to 2010. They forecast that population in the basin will reach 129 million in 2000 and 141 in 2010. Urbanization and increase of urban demand for water will increase to 3.1 billion cubic meters in 2000 and will increase to 5 billion in 2010. Rural domestic water use was estimated to be 2.05 billion cubic meters in 1994 but is forecast to increase to 2.2 billion in 2000 and 2.7 billion in 2010.

Industrial use water was estimated to be 4.5 billion cubic meters in 1984, rose to 7.6 billion in 1994, an annual average rate of increase of nearly 6 percent. They estimate that by 2000 industrial use demand will increase to 10.1 and will reach 15.5 billion in 2010.

If agricultural water use maintains its current level (assuming they were speaking about the level in 1994), then the demand for water in the basin will reach 50.2 billion cubic meters in 2000 and 57.6 billion in 2010. **This demand for water will far exceed the water resources of the basin.**

Hai Basin Commission Recommendations To Resolve the Supply/Demand Gap

The Li-Ma paper lists the following suggestions.

<u>Invest in Water Saving Projects</u>

They believe there is potential to save more water. Agricultural use water efficiency can be improved--improve the efficiency of canal irrigation. In the industrial sector factories should invest in water saving technology. Domestic water users also must become more efficient in delivering water from source to use.

They also noted that users in agriculture, industry, and domestic users need to develop and awareness of the water crisis and water problem. A water saving mind set or paradigm needs to be fixed in people's minds. Li-Ma realize in their paper that their Commission has a

responsibility to formulate effective policies, programs, and procedures to motivate users to employ water resources efficiently.

Further Develop Up steam Reservoirs

By building some upstream structures and by redistributing resources they believe they can squeeze an additional 1.28 billion cubic meters out of the basin.

Water Transfers from Outside the Basin Should Begin as Soon As Possible

They note that the studies on transferring water from the Yellow River in to the basin has already been completed. Water was temporarily diverted to help meet Tianjin water requirements in 1972, 1982, and 1983. They also note that water has been transferred to areas in Shandong and in Hebei provinces. They argue that more water should be diverted to the Baiyangdian project.

Latter in their paper Li-Ma mentioned that the middle transfer program is expected to be completed by 2030. They did not mention water transfers from the west route.

Recycle and Reuse Sewage

They note that in 1993 industrial wastewater amounted to 4.5 billion cubic meters while domestic sewage reached 1.3 billion cubic meters. There are 13 sewage treatment plants with a treatment capacity of 1.8 million tons a day or an annual treat capacity of 640 million cubic meters (a treatment ratio of about 12 percent).

Item	1993	2000	2010
Total waster water	5.781	8.229	12.053
Industrial	4.495	6.262	Na
Domestic	1.286	1.967	Na

They warn that cities should begin to build treatment plants to raise the proportion of wastewater which is treated.

Develop and Use Brackish Water

Li-Ma suggest that ways be found to use the large supply of brackish water which exists in shallow ground water in the eastern edge of the basin. They report that some 16,000 square kilometers of area in Tianjin, Hei-long-gan region in Hebei province, and in the northern coast of Shandong province have brackish water (2-3 grams of salt per liter of water). One way to reclaim the soil is to have plenty of fresh water to flush the salt out of the soil and a drain system to carry the salty water to the sea. Ms. Ma asked the Team if there were economically valuable plants which could grow in brackish water.

Use Sea Water

The Li-Ma paper notes that the Haihe basin is situated on the coast. One possibility is to use seawater in some industrial processes. Some industries in Tianjin have already begun to use seawater. Industries have found it more difficult to use seawater because of the impurities in the water but for some purposes such as cooling and de-dusting seawater is usable. Li-Ma argue that as the water crisis becomes more severe and water prices increase firms may find the use of seawater more attractive.

October Travel in the Hai Basin

On Saturday October 9th Frederick Crook and Mr. Sun, Ag Office, US Embassy drove about 520 kilometers through the Hai basin.

Alkali Problems in the Tianjin and Cangzhou Areas

From our travel in the area one could see alkali accumulations on levees. Farmers were reclaiming some fields by digging drain ditches about every 50 to 75 meters. The main crops grown on these fields included sorghum, sunflowers, cotton and corn. Crop growth was very spotty in the fields--some areas looked good and within a few feet the crop stands were poor.

Irrigation Wells Down to 300-400 Meters in Cangzhou

We stopped to talk to several farmers working in their fields. One family said the well they were using was drilled to a depth of 300 meters and then remarked that the neighboring fields had wells down 400 meters. They use under ground pipe to transport the water from the well to the fields. From the rising pipe they use a plastic hose to water each patch of winter wheat. Another farm family said the well they use was at a depth of 300 meters. They also used a plastic hose to water their winter wheat. In their case each little patch was about 4 meters wide and 6 meters long--bounded by small levees to hold the water. This system of irrigation is called qi-guan. Presumably this purpose of this system is to level a small patch of ground to minimize run off and to allow the water to soak into the soil.

They said the current cost of drilling a well and equipping it fully was 130,000 RMB. This cost was borne by the local production brigade (shengchan dui). T

Farmers were using their tractors and small diesel engines to drive the pumps in the fields. See Photograph 7-1)

Photograph 7-1--Tube well and Plastic Pipe in Cangzhou area.

Background on the Hai Basin•

Hydrologists define the Hai basin as that area which lies between the Songliao plain in China's northeast and the Yellow river basin to the to south and west. The basin has two river systems the Hai and the Luan and it includes all of Beijing and Tianjin municipalities, the whole province of Hebei and parts of Shandong, Shanxi and Henan. Hebei province administrative units totally surround the national level cities of Beijing and Tianjin (see map). The basin contains the very large cities of Beijing and Tianjin, 21 large and medium-sized cities such as Shijiazhuang and Tangshan 31 county level cities. About 60 percent of the basin is mountainous and 40 percent is in the plains area (Li Yan-dong, p. 1).

Before 1949 summer rains in the mountainous area to the north and west of the Hai river basin sent floods flowing through the Hai and Luan rivers to the sea. After 1949 officials embarked on a dam building project and constructed 22 large reservoirs in the upper reaches of these rivers. Miyun is the largest reservoir which can store 4.4 billion cubic meters of water. Workers constructed 90 medium sized reservoirs and 1,300 small ones so that the total storage capacity amounts to 20 billion cubic meters. By the mid-1970s the threat of flood in basin had lessened considerably. But by the early 1980s the drilling of hundreds of thousands of tube wells in the plains area brought the problem of water shortages (A Brief Review).

The Hai basin in 1994 had a population of 110 million and covered an area of 318,151 square kilometers. In 1994 the basin had a cultivated area of 10.8 million hectares of which 6.87 million hectares were irrigated. The agricultural population is 89 million and in 1994 total grain output reached 49 million tons. The gross value of agricultural output was 116 billion RMB and gross value from industry and township enterprises totaled 740 billion RMB (Li Yan-dong, p. 1).

The mean annual precipitation for the basin (1956-84) was 548 mm. Total net water availability of 42.1 billion cubic meters in the basin is the sum of surface water of 28.8 billion cubic meters plus 26.5 billion cubic meters of ground water less doubly counted water (the leakage of surface water into ground water) of 13.2 billion cubic meters (Li Yan-dong and Li Jia-san). Each person in the basin had an average of 430 cubic meters of water available per year which made it the driest regions in China. The estimated water consumption for the Hai river basin for 1997 is given in Table 7-1.

Ms. Ma's paper said that of the 41 billion cubic meters of water resources in the basin, surface water constituted 10.6 billion (which includes some sewage water discharge back into river courses without treatment); ground water 24.3 billion; water diverted from the Yellow River 5.7 billion, and 400 million cubic meters of brackish, treated sewage and seawater (Li Yan-dong).

• D:\water\99triprpt

Table 7-1-1998 water supply and use by river basin, in billion cubic meters

Basin	Water supply: Surface	Ground	Other	Total	Water use: Ag	Industry	Dom.	Total
Total	441.9	102.9	2.1	547.0	376.6	112.6	54.3	543.5
Song	34.0	28.3	0	62.3	45.1	12.3	4.9	62.4
Haihe	16.1	26.2	0.1	42.4	30.7	6.7	4.9	42.4
Yellow	26.9	12.8	0.2	39.8	30.8	5.8	3.0	39.5
Huai	39.1	17.6	0.2	56.9	40.9	9.5	6.2	56.7
Yangzi	159.4	7.0	1.4	167.9	97.4	49.7	19.2	166.3
Pearl	80.1	4.0	0.1	84.2	54.4	18.8	10.5	83.7
SE	29.8	0.7	0	30.6	20.1	7.2	3.5	30.8
SW	8.0	0.2	0	8.2	6.5	0.8	0.9	8.2
Internal	48.6	6.0	0	54.6	50.7	1.6	1.2	53.6

Source: Ministry of Water Resources. Zhongguo Shui Ziyuan Gongbao, 1998 (Annual Report on China's Water Resources, 1998), September 1999, page 13.

The Annual report suggests that water use ratio for the Hai basin in 1998 was 61.8 percent for surface water and 100 percent for shallow ground water.

The Annual Report for 1998 notes that the shallow ground water table in the North China Plain rose in 31 percent of the area (0.5 to 2.3 meters). But the water table decreased in 11 percent of the area compared with 1997 (0.5 to 1.4 meters). Ground water levels fell in Hebei province. The estimated quantity of shallow ground water in the Hai basin fell by 700 million cubic meters from 1997 to 1998. Source: Ministry of Water Resources. Zhongguo Shui Ziyuan Gongbao, 1998 (Annual Report on China's Water Resources, 1998), September 1999, page 10.

Cones of Depression

According to data from 21 provinces there are 81 cones of depression.

45 of these cones are in shallow aquifers. In 1998 compared with 1997 the level in the deepest part of the cone rose in 30 of these cones and fell in 15. The Suning depression in Hebei province dropped a great deal in 1998 (more than 3.5 meters). On the other hand the area around the Anyang (Henan) and Hebei's Gaoqing cone of depression decreased by 300 square kilometers.

There are 36 deep aquifer cones of depression. From 1997 to 1998 the water level rose in 14 of these cones and area of the cone decrease. But in 22 of the cones the water level fell and the area increased. The level rose by 5 meters in the cone beneath Tianjin. The area of the cone was reduced around Beijing city by 100 square kilometers. But the area of the cones expanded in Hebei provinces zao heng and Cangzhou which increased by 775 and 600 square kilometers

respectively. Zhongguo Shui Ziyuan Gongbao, 1998 (Annual Report on China's Water Resources, 1998), September 1999, page 10.

Table 7-2--Hai river basin water consumption estimates, and comparison with National consumption percentages

Sector	Billion cubic meter	Percent of total consumption	Percent of country total water consumption for 1980
Agriculture	32.3	84.3	88.2
Industry	4.9	12.8	6.7
Urban use	1.1	2.9	1.5
Hydro-electric	--	--	3.6
Totals	38.3	100.0	100.0

Source: World Bank, Clean Water, Blue Skies, World Bank, Washington DC, 1997.

Table 7-3—Hai basin compared with China's other water basins

River Basin	Area	Annual Stream runoff Total Volume	Percentage of national	Cultivated land	Population	Runoff Per ha	Runoff per capita
	1,000 Square Km	Cubic Km	percent	million hectares	million	cubic meter	cubic meter
Hai	319	28.3	1.0	11.3	92	2,505	308
Songhua	528	75.9	2.9	11.7	46	6,450	1,650
Liao	232	15.1	0.5	4.5	28	3,375	540
Huang	752	56.0	2.1	13.1	82	4,290	683
Huai	262	53.0	2.0	12.5	125	4,230	424
Chang	1,807	1,000.0	38.2	24.0	346	41,700	2,890
Zhu	415	307.0	11.7	4.4	74	69,750	4,150

Yao Bang-yi and Chen Qing-lian, "South-North Water Transfer Project Plans," in Biswas, Asit K., Zuo Da-kang, James E. Nickum, and Liu Chang-ming, Long Distance Water Transfer: A Chinese Case Study and International Experience. United Nations University, Tycooly International Publishing Limited, Ireland, 1983, p. 133.

Table 7-4-- Long-term annual hydrological balance of the Hai-luan basin

Region	Basin	Drainage	Precipitation		Runoff		Evapotranspiration		Precipitation Recharge to Groundwater	
		km^2	km^6	mm	km^3	mm	km^3	mm	km^3	mm
Mountains										
	Haihe	144,022	78.6	546	15.8	110	62.8	436	--	--
	Luanhe	46,618	25.3	543	5.2	111	20.2	433	--	--
	Subtotal	190,640	104.0	545	21.0	110	83.0	435	--	--
Plains										
	Haihe	120,595	68.7	570	6.8	57	--	--	--	--
	Luanhe	7,794	4.9	626	0.6	77	--	--	--	--
	Subtotal	128,389	73.5	573	7.4	58	60.3	470	5.8	45
Haihe basin total		264,617	147.3	557	22.6	86	--	--	--	--
Luanhe basin total		54,412	30.2	556	5.8	105	--	--	--	--
Hai-luan basin		319,029	177.5	557	28.4	89	143.3	450	5.8	--

Source: Li Jia-san, "Integrated Evaluation of the Surface and Groundwater Resources of the Hai and Luan He Basins," in Biswas, Asit K., Zuo Da-kang, James E. Nickum, and Liu Chang-ming, Long Distance Water Transfer: A Chinese Case Study and International Experience. United Nations University, Tycooly International Publishing Limited, Ireland, 1983, pp.234-243.

Hebei's Prefectures

Cross section data for Hebei's 11 prefectures is given here to help us understand the over all situation in the province.

Table 7-5--Hebei's prefectures

Code	Prefecture name	Arable	Irrigated	Area Grain	Grain	City in 1,000s
		Percent of Hebei totals				
1	Shi-jia-zhuang	9.12	13.29	11.10	16.18	1,472
2	Han-dan	10.36	12.46	11.39	11.22	1,214
3	Xing-tai	10.43	11.38	10.70	9.14	464
4	Bao-ding	12.39	16.84	15.03	17.43	669
5	Cang-zhou	12.05 10.17	12.16	8.77	403	
6	Lang-fang	5.69	6.64	6.09	5.72	600*
7	Heng-shui	8.96	9.28	7.86	8.12	337
8	Tang-shan	8.91 9.97	8.47	11.20	1,579	
Sub-total north China plain		77.91	89.96	94.01	89.91	
9	Qin-huang-dao	3.08	2.83	2.66	3.09	628
10	Zhang-jia-kou	13.80	5.23	10.02	4.79	803
11	Cheng-de	5.21	1.99	4.53	4.20	397

Source: Urban Statistical Yearbook, 1996, p.45. * other source.

Data from Hebei Statistical Yearbooks suggest that 78 percent of the province's arable land were in prefectures located on the north China plain. The prefectures of Zhang-jia-kou, Cheng-de, and Qin-huang-dao are located in the mountainous areas in the west, north and east parts of the province (see map).

In 1994 90 percent of the province's irrigated areas were in prefectures on the north China plain. The mountainous northern prefectures had only 10 percent of the irrigated area. Farmers in the plains area had 94 percent of the irrigation pumps registered in the province. Farmers in the prefectures on the north China plain produced 88 percent of the province's total grain output.

Irrigated Area in the Hai Basin

Farmers in the basin irrigated 6.225 million hectares of cultivated land in 1990, which was about 13 percent of China's total irrigated area. Hebei province, Beijing and Tianjin municipalities accounted for about 66 percent of the irrigated area in the basin.

Table 7-6--Irrigated area in the Hai basin, 1990

Province	Effectively irrigated area 1000 ha	Percent of effectively irrigated area Percent	Actually irrigated in 1990 1000 ha	Area irrigated by mechanical/ electric means 1,000 ha.
Total basin	6249	100%	5799	5682
Beijing	329	5%	309	290.7
Tianjin	346	6%	300	346.0
Hebei	3423	55%	3227	3129.3
Shanxi	383	6%	310	248.7
Neimenggu	19	0%	15	10.0
Shandong	1183	19%	1105	1149.3
Henan	567	9%	534	508.0

Source: MOWR, ZgSlNj, 1991, p. 672.

Well irrigation accounted for 67 percent (4,217 / 6249) of the area irrigated. In 1990 drip and spray methods accounted for less than 1 percent of the irrigated area in the basin.

We are not sure how to interpret this data. If the basin has 6.249 million hectares of effectively irrigated land and if 4.217 million hectares are irrigated by mechanical/electrical pumps, then does that mean that 2,032,000 hectares (or 33 percent) are irrigated by gravity flow irrigation systems?

Table7-7—Irrigation and drainage methods

	Mechanical/electric Irrigated and Drainage Area: Total of Irrigation & Drainage Area 1,000 ha	Mechanical/electric irrigated area: Irrigation sub-total 1,000 ha	Mech/elec Wells 1,000 ha	Fixed station 1,000 ha	Moveable Station 1,000 ha	Spray and drip 1,000 ha	Drainage Area 1,000 ha
Total basin	6094	5682	4217	971	433	61	412
Beijing	295	291	178	53	10	49	4
Tianjin	418	346	122	155	0	9	72
Hebei	3462	3129	3015	189	102	3	333
Shanxi	250	249	169	80	0	0	1
Neimenggu	10	10	9	1	0	0	0
Shandong	1151	1149	448	384	317	0	2
Henan	508	508	456	49	3	0	0

Source: MOWR, ZgSlNj, 1991, p. 672.

Accounting for Loss of Irrigated Land in the Basin

As might be expected in any dynamic rural economy new lands are brought under irrigation and other cultivated lands cease to be irrigated (some land indeed withdrawn from production). For example available data for 1990 indicate that farmers in the Hai basin brought 264,000 hectares of land under irrigation but lost 200,000 hectares leaving a net increase of 64,000 hectares. Details of this loss are in table 7-7.

Table 7-8—Loss of irrigated lands in the Hai Basin

Type of loss	Area in hectares	Percent of total loss
Discarded wells	128,000	64.0 %
State construction projects	17,000	8.5
Township construction projects	16,000	8.0
Other construction projects	12,000	6.0
Long term dearth of water supplies	9,000	4.5
Other reasons, not specified	20,000	10.0
Total loss from all sources	200,000	100.0

Source: MOWR, ZgSlNj, 1991, p. 672.

In 1990 64 percent of the loss of irrigated land in the basin came from discarded wells. The 1991 Yearbook does not indicate why the wells were discarded: pumps wore out? Casings damaged? Or water table dropped?

Reservoirs in the Hai Basin

Effectively irrigated area from reservoirs totaled 1,279,000 hectares, 20 percent of the effectively irrigated area in the basin. The 27 large reservoirs in the basin hold 82 percent of total basin storage capacity and water 67 percent of the irrigated area in the basin. Medium sized reservoirs in the basin hold 12 percent of the total basin's storage capacity and waters 20 percent of the basin irrigated area. Small reservoirs hold 6 percent of storage capacity and 13 percent of effectively irrigated area.

Table 7-9—Reservoirs in the Hai Basin, 1990

	Number of reservoirs numbers	Total storage capacity billion cu meters	Xingli kurong billion cu meters	Large/med reservoir water entering in one yr. billion cu meters	Effectively irrigated area from reservoirs 1000 ha.
Total basin	1372	27.698	11.175	13.882	1279
Beijing	83	9.303	2.384	1.598	224
Tianjin	91	2.521	1	1.283	77
Hebei	664	13.235	6.661	9.313	770
Shanxi	383	1.919	0.747	0.815	139
Naming	10	0.075	0.031	0.049	2
Shandong	0	0	0	0	0
Henan	141	0.645	0.352	0.842	66

Source: MOWR, ZgSlNj, 1991, p. 682.

7-10—Reservoirs, by size, in the Hai basin, 1990

Item	Unit	Total	Large	Medium	Small
Number of reservoirs By size	Number	1,372	27	103	1,242
Effectively irrigated area	1,000 ha.	1,279	859	260	161
Percent of effectively Irrigated area as a % of area irrigated	Percent	100%	67%	20%	13%
Storage capacity by Reservoir size	Billion cu. Meters	27,698	22,265	3,179	1,256
Percent of basin Storage capacity By res. size	Percent	100%	82%	12%	6%

Source: MOWR, ZgSlNj, 1991, p. 682.

Irrigation Districts in the Hai Basin

Of 6.249 million hectares of land irrigated in the Hai basin, MOWR reports that 2.477 million or 40 percent were irrigated through irrigation districts. Does this mean that 3.772 million hectares were irrigated outside of districts (single tube wells)?

Hebei and Shandong provinces had the largest area of land under irrigation districts at 38 and 36 percent respectively. MOWR statisticians collected irrigated land data by size of irrigation districts as follows: districts above 33,333 hectares; 20,000 to 33,333; 6,667 to 20,000; 667 to 6,667; and less than 667 hectares (see table 710). Districts above 33,333 hectares numbered only 9 but accounted for 33 percent of the irrigated area with districts. Much smaller irrigation districts (667 to 6,667 hectares) accounted for 31 percent of irrigated area within districts (see table 7-10).

Table 7-11—Number of irrigation districts in the basin, by size, 1990.

Province	Total	Over 33,333	20,000 to 33,333	6,667 to 20,000	667 to 6,667	Less than 667
Hai basin	568	9	11	51	403	94
Beijing	40	0	4	2	27	7
Tianjin	48	0	0	0	46	2
Hebei	153	3	2	25	106	17
Shanxi	83	0	1	7	64	11
IMAR	5	0	0	0	1	4
Shandong	212	5	2	12	142	51
Henan	27	1	2	5	17	2

Table 7-12—Irrigated area by size of irrigation districts in the basin, in 1,000 ha. 1990.

Province	Total	Over 33,333	20,000 to 33,333	6,667 to 20,000	667 to 6,667	Less than 667
Hai basin	2477	818	287	594	761	17
Beijing	208	0	105	36	64	3
Tianjin	67	0	0	0	66	1
Hebei	946	324	58	302	256	5
Shanxi	213	0	22	71	115	5
IMAR	2	0	0	0	1	1
Shandong	881	459	46	142	226	8
Henan	160	35	56	43	33	Na

Table 7-13—Irrigated area by size of irrigation districts in the basin, percent, 1990.

Province	Total	Over 33,333	20,000 to 33,333	6,667 to 20,000	667 to 6,667	Less than 667
Hai basin	100 %	33 %	12 %	24 %	31 %	1 %
Beijing	8	0	4	1	3	0
Tianjin	3	0	0	0	3	0
Hebei	38	13	2	12	10	0
Shanxi	9	0	1	3	5	0
IMAR	0	0	0	0	0	0
Shandong	36	19	2	6	9	0
Henan	6	1	2	2	1	0

Source: MOWR, ZgSlNj, 1991, p. 686.

Sluice Gates in the Hai Basin

In 1990 the basin contained 2,183 sluice gates. Hebei, Beijing and Tianjin had 78 percent of these gates. In terms of the sizes of these gates, 2 percent were large, 14 percent were medium sized, and the remaining 84 percent were small gates.

Table 7-14—Sluice gates in the Hai basin, 1990.

	Total Number	Large Number	Medium Number	Small Number
Total basin	2183	49	301	1833
Beijing	210	10	44	156
Tianjin	366	10	39	317
Hebei	1119	15	146	958
Shanxi	47	0	4	43
Naming	0	0	0	0
Shandong	381	14	56	311
Henan	60	0	12	48

Source: MOWR, ZgSlNj, 1991, p. 688

Dykes in the Hai Basin

In 1990 MOWR statisticians calculated that 24,657 kilometers of dykes in the basin protected 6.124 million hectares of arable land and 46 million people from floods. Dykes in Beijing, Tianjin and Hebei accounted for 73 percent of the total length of the dykes in the basin. These dykes in these 3 provinces protected 56 percent of the cultivated land and 60 percent of the population. Shandong and Henan provinces accounted for most of the remainder (see Table

7-14).

Table 7-15—Dykes in the Hai basin, 1990

	Length Km	Cultivated area protected 1,000 ha	Number of People Protected 1,000
Total basin	24657	6124	46286
Beijing	657	191	1950
Tianjin	4027	414	9698
Hebei	13303	2815	16200
Shanxi	855	43	778
Neimenggu	0	0	0
Shandong	3938	1268	8220
Henan	1877	1393	9440

Source: MOWR, ZgSlNj, 1991, p. 688.

Stock of Irrigation and Drainage Equipment in the Hai Basin

MOWR officials collected data on the number and kinds of irrigation and drainage equipment used in the basin in 1990. Power to operate these machines was measured in kw rather than in horsepower. Beijing, Tianjin, and Hebei province accounted for 73 percent of all sets of irrigation and drainage equipment. Electricity powered 42 percent of the machines while internal combustion engines accounted for the remaining 58 percent (see Table 15).

Table 7-16—Irrigation and drainage equipment in the Hai basin, 1999

	------------Totals----		-----------Electric--------		Internal combustion engines	
	Sets of Equipment 1,000 sets	kw	Sets of Equipment 1,000 sets	kw	Sets of equipment 1,000 sets	Kw
Total basin	2369	20160	999	8546	1369	11614
Beijing	65	712	64	704	1	8
Tianjin	95	1312	78	1170	17	142
Hebei	1556	12547	628	4789	927	7759
Shanxi	29	406	29	397	1	10
Neimenggu	1	17	1	16	0	1
Shandong	468	4052	79	674	389	3378
Henan	155	1113	121	796	34	317

Source: MOWR, ZgSlNj, 1991, p. 691.

Pumping Stations in the Hai Basin

MOWR personnel listed the number of pumping stations in basin at 18,474. In Table 7-16 below we list the number of installed sets of pumps rather than the number of stations because installed pumps more clearly reflect the station's ability to move water. Fifty six percent of installed pumping station capacity in the basin is in Beijing, Tianjin, and Hebei province. Electricity powered 91 percent of the pumps with internal combustion engines providing 9 percent of the power to pumping stations in the basin.

Table 7-17—Pumping station capacity in the Hai basin, 1990.

Place	Totals Installed		Electric pumping stations Installed		Internal combustion engines Installed	
	1,000 sets	Kw	1,000 sets	kw	1,000 sets	Kw
Total basin	29.8	1375	26.9	1253	2.9	122
Beijing	6.5	136	6.5	135	0	1
Tianjin	4.7	418	4.7	417	0	1
Hebei	5.6	365	4.8	328	0.8	37
Shanxi	5.1	144	4.7	140	0.4	4
Neimenggu	0	0	0	0	0	0
Shandong	4.4	198	3.1	130	1.3	67
Henan	3.5	115	3.1	103	0.4	12

Source: MOWR, ZgSlNj, 1991, p. 694.

Number and Kinds of Wells

Beijing, Tianjin, and Hebei province accounted for 73 percent of the wells in the basin. Shandong and Henan provinces accounted for 12 and 13 percent of the remainder of the wells. Wells powered by mechanical means (presumably mostly internal combustion engines numbered 303,000, 32 percent of the total number of wells in the basin. Electricity powered 633,000 wells, 68 percent of the total. The MOWR 1991 Yearbook noted that 65,262 new wells were drilled in 1990 while 40,106 wells were discarded. No information was given about why the wells were discarded.

Table 7-18—Number and kinds of wells in the Hai basin, 1990.

	Number of wells	Mechanical	Electrical	Number of new wells installed	Number of Wells discarded
	1,000s	1,000s	1,000s	Number	Number
Total basin	906	303	633	65262	40106
Beijing	43	1	42	1429	943
Tianjin	24	1	26	533	806
Hebei	600	196	409	52699	30019
Shanxi	20	0	23	758	896
Neimenggu	1	0	1	169	273
Shandong	110	88	26	5147	3980
Henan	108	17	105	4527	3189

Source: MOWR, ZgSlNj, 1991, p. 695.

Supplying Potable Water for Consumers in the Hai Basin

Many rural citizens in China have had difficulties over the centuries finding safe and ample supplies of drinking water. By the early 1990s drinking water for some 18.7 million citizens had been found. But some 27.7 million citizens in the Hai basin continued to have difficulties finding adequate supplies of drinking water. MOWR, ZgSlNj, 1992, p. 666.

China's first agricultural census was conducted in January 1997. The newly published Abstract, November, 1998 suggests that in the 1990 decade considerable progress had been made. Partial data (we only summed up information from Beijing, Tianjin, and Hebei as being totally within the basin) suggests that by 1997 the number of persons having difficulties finding drinking water was reduced from 18 to 2 million rural residents (see table 7-8).

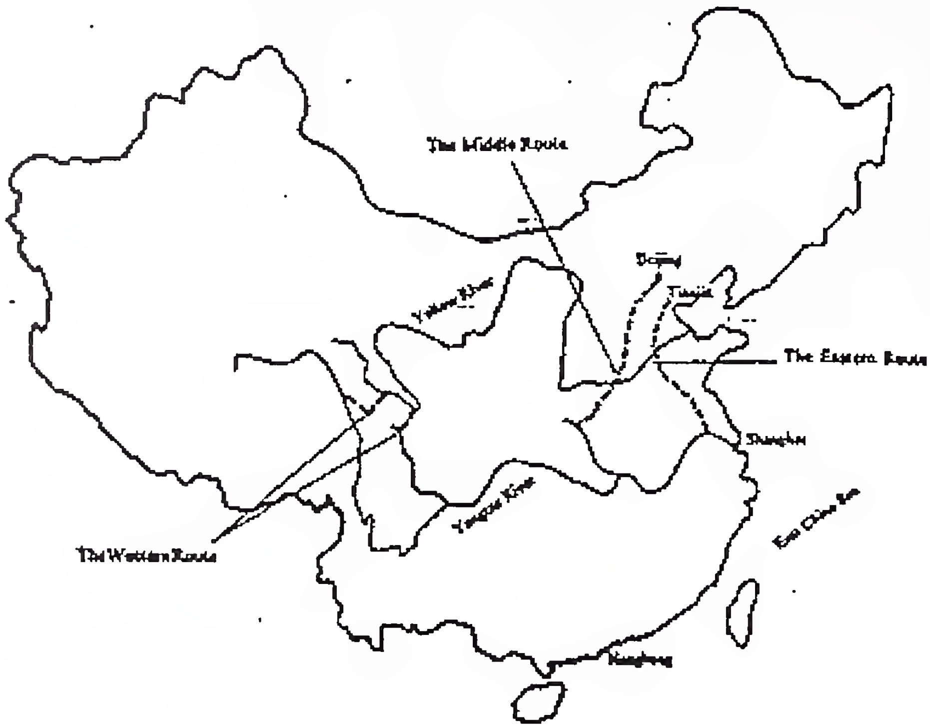
Table 7-19--Sources of drinking water for rural population in the Hai basin

Province	Tap water	River and lakes	Ponds	Wells	Other sources	Number of persons having difficulty getting access to water
	1,000 persons	1,000 persons	1,000 persons	1,000 persons	1,000 persons	1,000 persons
Beijing	**3201**	**9**	**0**	**847**	**50**	**65**
Tianjin	**465**	**4**	**1**	**3458**	**3**	**67**
Hebei	**32719**	**91**	**177**	**19517**	**269**	**1532**
Shanxi	3124	491	347	16900	1784	3724
Neimenggu	1543	65	15	12021	174	1342
Shandong	2440	296	494	61084	118	1308
Henan	622	686	675	70863	885	3414
Hai basin	36385	104	178	23822	322	1664

Source: National Agricultural Census Office, Abstract, November 1998, p. 163.

Map7-3—Map of East and Middle Routes for Diverting Water To the Hai Basin

Three Routes of Water Diversion From South to North



Chapter 8

Yellow River Basin

Xinshen Diao

The Yellow River Basin is the cradle of Chinese civilization. The river is China's second longest, at 5,464 km with a basin area of 795,000 square km. Its source is in the foothills of the Bayankala Mountains on the Qinghai-Tibetan Plateau. It passes through nine autonomous regions and provinces (Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan, and Shandong) before emptying into the Bohai See, supporting on its way a population of 140 million people, arable land of 16 million hectares, and more than 50 large and medium sizes of cities.

The basin is divided into three distinct sections: the upper, middle and lower reaches. The upper reach, with a drainage area of 384,000 square km, lies between the source and the gauging station Hekouzhen in Inner Mongolia (the start of the Yellow River's great turn to the south). The vertical drop in this region is 3,231 meters, making the reach ideal for hydropower generation. On average, 56 percent of the basin's runoff is to the upper reach. The two largest reservoirs in the basin, Longyanxia and Liujiaxia are located in its upper environs, and two more large reservoirs are under construction. Minimal precipitation, 300-600 mm per year, falls on most of this area, which has limited water demand, while the lower stretch of the upper reach, from Lanzhou north to the Mongolian steppe-lands, has large and growing irrigation demands. These demands are difficult and costly to meet: the distribution system is poor and loses are high, and in places water must by pumped up to a height of several hundred meters.

The middle reach, with a drainage area of 344,00 square km between Hekoushen and Huayuankou, lies between 1,000 and 400 meters above sea level and encompasses the Loess Plateau, and two of the Yellow River's major tributary basins, the Fen River Basin in Shanxi and the Wei River Basin in Shaanxi, both of which rely on the Yellow for much of their irrigation demands. Water supplies to this reach are invariably short; groundwater extraction is often excessive, and water diverted from the Yellow must often by pumped to a height of ten meters or more. The middle reach also contains large concentrations of population, industrial complexes, and mining, all significant and growing water consumers.

The lower reach begins near Huayuankou and stretches to the Bohai Sea. Most of the area is alluvial plain brought about by the meandering of the Yellow River. The lower reach contains most of the irrigated land in the basin, and on the whole is the most productive. Its temperate climate permits year-round cropping, and even paddy production is significant in its southernmost area. Rainfall is sporadic, but often sufficient to grow most crops and obtain adequate yields without irrigation. However, irrigation is widespread, involving complex systems to make maximum use of Yellow River water when it is available (and at acceptable silt concentrations) as well as groundwater. Both are used conjunctively and are often stored in field ditches along with reusable drainage water. The lower reach is disadvantageously situated on three counts: (a) in period of shortage, it is last in line to receive water; (b) it is most prone to

suffer the consequences of flooding; and (c) it must deal with most of the silt deposited in the river from upstream regions.

Even though Yellow River contains the highest sediment concentration of any river in the world, it is not the main concern of China's planners, nor is it the river's ability to support an ever-growing number of people, both rural and urban, and industries, mines, oilfields, and fisheries. The primary concern is flood control. There is significant year-to-year deviation in river's runoff. For each gauging station along the main stream of the river, the largest annual runoff was as high as 3 to 4 times of the smallest one. Moreover, the runoff during June to October accounts for 60 percent of year round runoff, while it only accounts for 10 to 20 percent during March to June. Hence, the large runoff during summer can cause serious floods, which in the past have killed millions, disrupted the lives of tens of millions, and caused incalculable property and economic loss since the earliest civilization appeared along its banks.

The second concern of Yellow River planners is sediment control. The Yellow River has the highest concentration of sediment in the world – nine times that of its closest competitor, Ganges (World Bank, 1993). The river carries 1.6 billion tons of sand into the sea each year, and the sand contention rate reaches 35 kg per cubic meter. Moreover, most of sand comes into the river in its middle reach. The upper reach, i.e., between the source and the gauging station Hekouzhen, only provides 9 percent of total amount of sand carried by the river, even though the upper reach accounts for 51.3 percent of the length of the river and 53.9 percent of the total water volume of the river. In the middle reach, especially between Hekouzhen and Longmenqui, along the border of Shaanxi and Shanxi provinces, more than 56 percent of sand carried by the river comes from this area, while the area only accounts for 2.5 percent of total water volume of the river.

Irrigation to feed the 140 million people residing in its environs is also important for planners. Irrigated area accounts for around 40 percent of total cultivated land in the basin but produces 60 to 70 percent of all crops. Without irrigation, farming in the basin is a marginal activity at best, with very low yields and incomes. However, most of the runoff of Yellow occurs in the summer months, while the winter and spring, when crops most need water, are typically dry. Year-to-year variation is also large, with five- or ten-year droughts not uncommon. Groundwater has been used to great advantage to supplement river supplies for irrigation and water supply, but there is evidence that the demands may be rapidly outstripping recharge rates in some areas.

Water Shortage Situation in the Basin

Even though Yellow River is the second longest river in the country, the average annual runoff only accounts for 2 percent of runoff of all rivers in the country. According to 1980s data, the average annual runoff at the upper and middle reaches of the river was 794 and 4,740 cubic meters per capita and per hectare cultivated land, respectively. The per capita runoff is equivalent to 30 percent of the national average level, while per hectare runoff is also lower than the national average level. Within the Yellow Basin, water resource is about 593 and 324 cubic meters, respectively, for per capita and per mu (1/15 of a hectare) of cultivated land. Such water resource levels are equivalent to 25 and 17 percent of the national average levels, respectively. The water resource in the middle reach of Yellow is more in shortage, about one-eighth of the

national level, given the annual precipitation being under 400 mm for more than 60 to 70 percent of the area. About 20 percent of the area, the annual precipitation is lower than 200 mm.

Demand for water has rapidly increased in the last four decades. The total annual volume of water delivered through various channels has reached 48 billion cubic meters during 1990s, while it was only 7.4 billion in the early of 1950s. Among the total annual water use, more than 11 billion cubic meters are ground water. The overdrawing is quite serious in many places in the Basin. The use of river water accounted for more than 36 billion cubic meters, as high as three times of the level in the early 1950s.

Irrigation needs more than 40 billion cubic meters annually, accounting for 85 percent of total water consumption in the basin. Urban and industrial use accounted for 5.7 billion cubic meters, 12 percent of the total, while rural domestic use accounted for 1.4 billion cubic meters, three percent of the total.

The available water resource in the Basin is about 62 billion cubic meters, 46.4 billion from rivers and other surface water and 15.6 billion from the ground. The forecasted water demand, according to the Commission, will reach 64 and 65 billion in 2000 and 2010, respectively.

The unbalance between water resource and water demand as well as the deterioration of water environment due to overdrawing ground water have become more serious in recent years in the basin. Conflicts exist between different water users, such as between urban and rural or industry and agriculture, among regions along the river bank, even among different gauging stations within a region, as well as between water use and hydropower, fishery, and river transport.

Similar with other places in China, water shortage is not reflected by its price, i.e., water usage costs are low both for urban and rural users. According to the World Bank (1993), the water charge for urban and industrial water supply ranges from 0.2 to 0.32 RMB per cubic meter. While the new water resource fee has just begun to be implemented for urban and industrial users, this charge is still quite low, about 0.05 RMB/m3.

Farmers do not pay anything near the opportunity costs of their water. The average value of water used in irrigation is found to be about 0.24 RMB/m3, while the marginal value, at critical times and in the most productive regions, is about 0.50 RMB/m3. Water charges range from about 0.05 RMB/m3 in parts of the upper reach to 0.045 RMB/m3 in Shanxi in the middle reach and averages about 0.025 RMB/m3 (0.5 /m3). (These values are very rough estimates because of the complex nature of water pricing, which involves one or more of the following components: volumetric charges, fixed charges, area-based taxes, and contributed labor for system maintenance.) These charges are only a fraction (17 percent) of the average return to irrigation and are even less for the marginal returns. In most parts of the basin, it is doubtful that water charges cover the full costs of system operation and maintenance. In 1988, MOWR and Ministry of Finance issued guidelines that required that water institutions become financially autonomous. They required that water fees be raised over a period of 5-10 years to recover all costs (essentially marginal cost pricing). Since then, water fees in several provinces have been increased dramatically to cover at least 65 percent of the marginal costs. These price increases

still fall far short of the opportunity costs of water during critical periods (16 percent) and as an average (34 percent) throughout the year.

Functions of the Yellow River Water Conservancy Commission

The MOWR is responsible for overall basin-level planning, but must coordinate all investments with the State Planning Commission. MOWR's local arm, the Yellow River Water Conservancy Commission (YRCC) plays the leading role in carrying out regional studies, identifying and designing projects, and promoting sound water use policies. It also undertakes a coordinating role among the nine provinces that the basin encompasses. These provinces also plan, invest, and make policy, sometimes in unison, and sometimes at odds with one another and YRCC. Complicating matters still further is the jurisdiction that the Ministry of Electricity has control over all hydropower installations.

Water Use Quota Allocations Across Provinces

There exists water use quota for each province along Yellow River. The allocation of the quota is done by the central government, while the Commission is the agency to monitor its implementation. There are three documents issued by the State Council in 1998 regarding to the water allocation of Yellow River. According the "Yellow River Available Water Allocation Management Method", one of the documents issued by the State Council, six provinces in the upper and middle reaches of the river are allocated up to 60.6 percent of total available river water, totally there are nine provinces along Yellow. The amounts of water allocated to the six provinces are: Qinghai, 1.41 billion cubic meters, Ganshu, 3.04 billion, Ningxia, 4 billion, Inner Mongolia, 5.86 billion, Shaanxi, 3.8 billion, and Shanxi, 4.31 billion. According to the officials from the Upper and Middle Reaches Management Bureau, there still exists overuse of the water beyond the allocated quota among some provinces.

Monitoring Water Drawing

According to the distribution of major responsibilities among different bureaus within the Yellow River Conservatory Commission, the Upper and Middle Reach Management Bureau is in charge of monitoring water drawing from the main stream of Yellow River between the source and the Yumenkou gauging station in Shaanxi province as well as main streams of Wei River and Datong River, two main tributary rivers in the upper and middle reach of Yellow. Specifically, the Bureau only monitors the drawing of large quantities of water, while the drawing of small amounts are controlled by the Bureau are monitored by the water bureaus at the provincial level. The levels that have to be controlled by the Bureau on the main stream of Yellow River and its basin are as follows: water drawn for irrigation with designed facility ability over 15 cubic meter per sec., urban and industrial water use drawing amount above 80,000 cubic meters per day, and underground water drawing more than 20,000 cubic meters per day. The drawing amount is also controlled for each monthly amount, together as an annual examination. Moreover, water users have to report the quantities drawn every ten days.

Managing Water Use License

After the implementation of the water drawing permission regulation issued by the State Council in 1993, the Commission and hence the Bureau are assigned a function to manage the water drawing license. The water use levels permitted by the Bureau are the same as above, i.e., 15 cubic meter per sec. for irrigation, 80,000 cubic meters per day for urban and industrial use, and 20,000 cubic meters per day for ground water. The Bureau is going to implement this regulation to all current water drawing projects. For river water, the drawing license is issued at each gauging station along the river. To build a new project which will draw water, the water user has to apply for the drawing rights before construction the project begins.

Soil and Water Conservation

The major duty of the Bureau is the soil and water conservation in the upper and middle reaches of Yellow Basin. There are only 11 staff members in the Bureau to in charge of the water drawing monitoring and management, while more than 200 persons are involved in the work of soil and water conservation. Soil and water conservation work received more attention by the central government in the last three years. Before 1997, only 20 million RMB was allocated to this work through the Bureau. In 1997, the funds increased to 70 million, and 150 million for 1998. It is estimated that it can reach 200 million in 1999. All this funds are from the central government's fiscal budget, while the World Bank loan is about 150 million U.S. dollars during 1994 and 1999, and another 150 million starting from 1999. The funds are further allocated to each water bureau at the provincial level (while the World Bank's loan is managed by the World Bank Project Office at each provincial government).

The focus of most projects is small tributary basins along the upper and middle reaches of the river, which allows farmers to take part in the projects. To start a project, the project plan has to be made first. Once the plan is proved by the Bureau, the project is recognized (Li xiang in Chinese). Then the project design can be started. The project has to consider comprehensive treatment of one small basin, i.e., combining river and mountain treatment with economic development in this area, such as agriculture, forestry and grass, as well as road construction.

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Professor Kang Yao-hu
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